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A type of primitive native loom, used at Fumban, Cameroon

NATIVE INDUSTRIES OF GERMAN CAMEROON (See page 344)

Colloidal Fuels*

Coal Combined with Petroleum Fuel-Oils, with or without Coal Tars

THE Executive Committee of the Submarine Defense Association at 141 Broadway, New York, has authorized the release of a statement concerning the new Colloidal Fuels developed under its auspices since the United States entered the war and now fully tested and demonstrated. The Submarine Defense Association was organized in June, 1917, by the companies whose names appear on this brochure, representing the shipping and marine insurance interests of this and other countries to assist in developing effective anti-submarine measures.

The assistance of the United States Navy Department was extended to it and constant facilities were thus privided for working tests at sea. In 1917 and 1918 the situation in England, France and Italy was so serious as to threaten a possible paralysis of naval movements. The emergency mobility of the Grand Fleets that stood watch and ward through nearly four and a half years of sea-guardianship depended on oil fuel, yet the liquid-fuel supply was put in constant jeopardy by submarines. In 1918 the British Admiralty widely advertised a reward for a means of mixing oil and coal-tar for naval fuel use. The submarines sunk cost prodigious efforts on the part of the navies of Britain, France, Italy, Japan and the United States. In forced expenditures and losses, direct and indirect, which have to be met by endless taxes, loans and interest, each submarine sunk has taken a toll of easily a hundred million dollars. Out of persistent peril and menace grew the renewed search for a practical colloidal fuel. With the fact that through it, ample liquid-fuel reserves could be made available within the borders of England would come the assurance that no submarine successes could be won, which would keep those fleets from the exercise of the sea power which would make victory in land ultimately certain.

Mr. Lindon W. Bates, chairman of the Engineering Committee of the Submarine Defense Association in New York, in whose hands rests the commercal introduction of *colloidal fuel* and who has had personal direction of its development, with competent technical assistants, made recently a report now given publicity. Mr. Bates had known the oil industry for many years. With the fields of Peru, Russia, Trinidad and others he had been intimately associated. At the beginning of the European war he began this specialized study of the oil-fuel situation in the Unted States and Europe and its relation to the submarine menace.

In making an oil-and-coal composite an insuperable difficulty heretofore has been the persistent settling out or sedimentation of the heavy coal and tar particles. This destroyed the value and utility of all mechanical mixtures. Until now the best that in a practical way chemical science could do was, with the aid of tannin, to suspend in oil less than one per cent. of Atcheson graphite 75 mm. in average size.

Knowing the availability of coal abroad where oil has all to be imported and being familiar with previous experiments and the age-old efforts, he turned to certain new measures in hope of succeeding despite the past.

Today it is possible to suspend for months in oil 30% to 40% of coal, pulverized so that about 95% passes through a 200-mesh screen, assisting the suspension with a special fixateur. The average size of the coal particles is many times that of the graphite particles in lubricating compounds. It is now possible to combine a stable liquid fuel about 45% oil, 20% tar and 35% pulverized coal, thereby replacing over one-half of the oil, securing equal or greater heat values per barrel and saving considerable cost. Asphaltic and free carbon particles in pressure-still oil may also be stabilized, thereby rendering available for metallurgical uses a low sulphur oil.

Pulverized coal burned alone cannot in many cases replace oil. Especially is this true on shipboard. Radical changes in oil-burning installations become necessary, its storage requres too much space and thus limits the cruising radius of war vessels.

The new colloidal fuel has received most thorough investigation on land and sea. The vessel assigned by the U. S. Navy Department to the Association for experimental and demonstration purposes was equipped with Normand Express Boilers. With practically no changes in the oil-burning equipment, colloidal fuel has been burned and stored for months on this ship. Trials in Long Island Sound have been made before representatives of our own and several Allied Navies, official bodies and corporations, some of which have followed the tests with permanent representatives. For land use a fuel plant has been installed at one of the large refineries and its results confirm all claims.

Industrially colloidal fuel will have an abiding value in all countries. For naval use it will be valuable where liquid fuel is dear as in England, France and Italy, and where long radius of steaming is desirable.

"For Italy the lean lignites of Sicily and those of the villa-dotted Arno Valley are given value as with the magic of a spell. For France what she has left of coal is transmuted into gold. The fuel-life of England is lengthened. All her Empire and all the earth where carbon seams its bosom, is enriched for men will have it longer to use an to enjoy.

The primary objects of the original research combinations of fuel referred to and of their tests and demonstrations were:

1. To conserve the oil-fuel supplies available to the Allies, who depended for these on oversea transport.

2. To relieve the strain on oil transport by tankships whose fleets, with steadily heavier duties to perform, were being decimated.

3. To enable the American, British, French and Italian navies to use less oil, yet to maintain to the fullest measure their cruising and emergency speeds, or to increase the patrol-mileage practicable with the present consumption of oil.

There are achieved several other objects—one to permit the conservation of American oil and coal without sacrifice, hardship or loss of industrial efficiency; another to enable greater use of the high sulphur oils or coals by averaging down the sulphur content in the mixed fuels burned; a third object, through lessening refinable oil consumption in metallurgical, navy and railway use, to leave more to refine for valuable products; a fourth to enable the cheaper and poorer coals and those high in ash content to be burned with the best efficiency, now that the world's high grade coals are being gradually exhausted."[1]

The report briefly outlines the situation.

Pulverized coal can now be successfully held in suspension so that the colloidal liquid flows freely through the pipes, preheaters and burners of ships and power, heating and industrial plants equipped to burn fuel oil. Months after mixing, the composites show little or no deposit. A fixateur, which comprises about one per cent. or twenty pounds per ton acts to stabilize the particles of pulverized coal dispersed in the oil. In colloidal fuel every solid particle has its film of liquid hydrocarbon and a protective and peptizing colloid, itself combustible. These particles are in three classes as to dimensions—coarse, colloid and molecular. By coarse is meant here the fineness of fifty million particles per cubic inch. The fixateur and fixated oil are readily made and may be shipped anywhere. The manufacture or distribution of the new fuels incorporating solid carbons in fixated oils involves no doubtful process or industrial problem. On burning, the combustion is so complete that with fair coal there is left no slag and very little ash, what there is being light as pumice and granular as sand.

It is the property of colloidal fuel that without loss of efficiency per unit volume or change of oil storage or burning equipment it makes possible the conservation of at least twenty-five per cent. of the fuel oil now burned or conversely with the oils now available it increases by fifty per cent. the world supply of fuel that is liquid. "We may go further and state that a number of new fuels have been realized, each with varying percentages of oil and solid carbon. One useful composite, in the range of ordinary temperatures, is composed of about half coal and half oil. Another unctuous semi-liquid is nearly three-fourths coal and one-fourth oil. All the fuel pastes are mobile to sustained and easily applied pressure and may be thus pumped, fed and atomized in the combustion chamber." These semi-fluid composites will constitute the most compact and safest fuel for domestic and industrial use and they will largely eliminate the smoke and ash nuisances of cities.

For example:

Industrial colloidal fuel, grade No. 10, devised to use up some poor coal holding 25.5 per cent. ash, is composed of 61½ per cent. of pressure still oil, wax tailings, petroleum pitch and fixateur running 18.505 B. T. U. per pound and 38½ per cent. of "anthracite rice" running 10.900 B. T. U. per pound. This grade contains 162.500 B. T. U. per gallon, and had 10.2 per cent. of ash. The fixated oil itself had 151.750 B. T. U. per gallon. In fuel value therefore the colloidal fuel of grade No. 10 is worth 7½ per cent. more per gallon than the oil from which made.

If instead of "anthracite rice," very high in ash, a crude oil coke which is ashless had been employed, the colloidal fuel gallon would have contained 182.154 B. T. U. or roundly 20 per cent. more than the oil base and only ¼ of 1 per cent. sulphur.

It is interesting to note that the mobile paste which is about half oil and half coal has the largest number of B. T. U. per unit volume of any proportion. With higher coal percentage, the total B. T. U. content per gallon diminishes gradually.

"Colloidal fuel can be utilized for marine steaming purposes under practically the same conditions and with as good results as with the navy (high grade fuel) oil. The saving of oil for equal weights on the Naval Research vessel was 31.2 per cent. The Naval Brand colloidal fuel had nearly 2 per cent. less volume for equal heat units than the oil with which it was made. . . . This will mean with the same tank or bunker space a longer "cruising" radius with re-fueling, or conversely, that storage can be smaller, and less actual volume of fuel need be carried. Colloidal fuel requires no different equipment from that used to burn fuel oil. The burners need be no larger and are easily kept clear of deposits; there has been no choking of pipes, and storage has presented no difficulties; the coal has remained in suspense for months and when sedimentation begins, a short stirring renews the life of the composite as regards the suspension of carbon particles or the dissolution of a forming gel."

The submarine compelled a preference for smokeless fuels. Tests have shown that this new colloidal fuel is as smokeless as the Navy's high grade fuel oil, yet by over-firing with it a dense smoke screen can be generated.

Colloidal fuel, made with Navy oil, has now been amply demonstrated at sea. Four reports have been printed giving data of tests.

It is certain that brands or grades of colloidal fuel may be prepared which will give a warship or a merchant ship up to 20 per cent. more steaming radius without refueling than the fuel oil to Navy specifications contained in the same tanks.

As an example of conservation to be effected through the new colloidal fuel, the report gives an estimate of what would result by its substitution for the 2,900,000 barrels of oil now consumed yearly in the power plants of New England. By displacing only 25 per cent. of the oil with pulverized coal a saving of 675,000 barrels would be secured. Estimates of the cost of this new fuel indicate a valuable reduction in the fuel expenses of New England power plants. Moreover in New England, graphite anthracites, gas-house coke and tar, and charcoal can be used effectively. Thus there may be a marked saving of transport—30 per cent. as to oil and 30 per cent. as to coal. On the other hand the 2,900,000 barrels brought to New England when employed in colloidal fuel can do the work of nearly 4,000,000 barrels with the marked economies and advantages inherent to producing and applying heat with liquid as against solid fuel.

Regarding the saving of cost involved in the use of colloidal fuel, the Submarine Defense Association's pamphlet states:

"For example, with coal at $4.00 per ton and oil at $4.00 per 50-gallon barrel, the saving is $2.00 per ton. This is an average peace condition in New York City. If coal is $5.00 per ton and oil $7.00 per barrel, the saving is close to $6.00 per ton. These savings are quite apart from the conservation of oil and reduction of transport."

Each locality may have its special composite containing the cheapest available coal, oil and other ingredients. Each duty will be best accomplished by a brand to some determined specification. Ships may thus obtain the cheapest liquid fuel in any port. Land plants and railroads may buy from refineries any grade of colloidal fuel they desire to the prescription wanted or they may obtain the appropriate fixated oil and make the final composite themselves as and when required. No change in oil storage or burning equipment is necessary.

A demonstration test unit, to manufacture and use colloidal fuel on land is installed in Brooklyn. The fuel made is burned for power purposes in the works. In addition to those taken on the naval vessel, precise evaporative and efficiency tests have been made according to the rules prescribed by the Codes of 1915 issued by the American Society of Mechanical Engineers.

*Communicated by *The Submarine Defense Association*, New York.

[1] "Colloidal Fuel Composites of Oil and Carbon," Lindon W. Bates, 1918, p. 6, 7.

Colloidal fuel made with pressure-still residuals—oil, wax tailings, crude oil coke—is another most gratifying success. These residuals are the Cinderella products of refining. Liqued fuel so made may add in this country to each year's stock of available fuel-oil many millions of barrels, without increase of oil-well production or strain on rail or sea transport. From these residuals, a fuel is prepared so low in sulphur that it will command a premium because valuable in making higher grade alloy-steel.

It has come to be realized that colloidal fuel is not only available for the advantageous conservation of oil for Navy and merchant-ship uses overseas, but for power and heat production on land in nearly all countries. The largest field of use and oil conservation is in furnace work—direct fired, reverbatory, regenerative and crucible furnaces for brick kilns, for air, annealing, bolt heading, blacksmithing, brass melting, billet heating, forging, rivet heating and open hearth furnaces now fitted for oil. About 70 per cent. of the oil they now use will do the present duty of 100 per cent. and do it more cheaply. A certain steel plant uses 3,000 barrels of oil daily and it will soon require 4,500 barrels. But the 3,000 barrels of oil with coal incorporated and used in colloidal fuel will be ample for full output, saving about 500,000 barrels per annum with less cost and with great conservation of actual oil and oil transport. There are legions of liquid fuel users large and small. As a corollary of these developments there will be very many more.

A further research was started by Mr. Bates, in response to a suggestion from the Admiralty, to try blending petroleum oils and coal tars and see if it were practicable to stabilize the mixture so that free coke and asphaltic substances would not settle out, but would produce a stable liquid fuel that could be shipped, piped and stored. The quest was well worth while because should it succeed one might so create annually here and in England up to twenty million barrels of superior liquid fuel without an increase in oil-well production. Success is now confirmed. Thus countries without oil like Australia, France, Italy and England, may themselves produce over half of the substances to make liquid fuel, and as the gas-house and coke-oven tars are usually cheaper than fuel-oil they will average down the cost of oil in the composite.

As world wants exist and grow a serious scarcity of oil may develop. There are five things only that may be done to meet this:

a. Increase the production of oil.

b. Save waste.

c. Diminish use.

d. Conserve oil by incorporating coal to make colloidal fuel.

e. Augment the supply of fluid fuel by finding new sources in tar and pressure-still oil and fluidized coal.

The last two means are accomplished by the new colloidal fuel. Shortages may be obviated thereby, not alone without industrial hardships, but in most cases with less cost, and the steel products will have higher tensile strength and better qualities.

Heretofore in ordered civilized life we have had three classes of fuel to use:

First—Fuels solid at ordinary temperatures, including coal and derivatives—Brown, Lignite, Bituminous, Anthracite and Cannel coals, coke and pitch, vegetable growths and derivatives, like charcoal, pitch and sawdust; petroleum-asphalts and allied solid substances.

Second—Fuels liquid at ordinary temperatures, including petroleum and derivatives, principally "fuel oils;" liquid derivatives of the distillatons by varous processes of coals and woods, asphalts and alled substances into light oils, middle fraction oils and tars; alcohol and similar substances; vegetable oils, animal oils and molasses.

Third—Fuels gaseous, either artificial or natural.

Of the liquid fuels practically only "fuel oils," tars and alcohol are used for heat and power production—alcohols, animal and vegetable oils only for small domestic purposes—and molasses as an emergency fuel in sugar making.

To these three classes must now be permanently added a fourth—the colloidal, uniting the solid and the liquid and consisting of synthetic fuels in a colloidalized state in three sub-classes:

a. Liquid colloidal fuels.

b. Mobile colloidal fuels.

c. Solid colloidal fuels.

To produce colloidal fuels there are required: first, certain processes modified to suit the blend or grade desired; second, certain fixateurs. Their offices are primarily to stabilize synthetic fuels whose separate elements are of different specific gravities and characters, so that the finished products have each a homogeneous and definite nature.

Regarding the nature of the fixateurs and special incorporation and treatment process, it will suffice to say that the fixateurs and treatments produce a state in which the settling force of gravity, operating upon the particles somewhat according to Stokes' Law, is overcome by peptization, absorption, Brownian movement, electrical factors and other chemical and physical phenomena, including such as obtain in colloids of metals, only that in the new case many of the particles are above solloidal size.

Third—Certain substances incorporated during the main process or when forming the "fixateur" which is itself incorporated. Their offices and properties are to affect chemically or physically or electrically, the characteristics of the components of colloidal fuels either alone or in association with liquid or other substance combustible or non-combustible. They have properties in particular reference to: Suspending and dispersing solid particles of coarse, colloid and molecular dimensions (coarse being used in a relative sense), or fluid sludge or asphaltic ooze, in a liquid or mobile gel or paste dissolving and peptizinz; establishing the desired viscosity, melting or fusing pont, the chilling range or the desired flashpoint; fluxing; enriching with combustible elements; dehydrating or hydrating; affecting the ash content and the sulphur content on combustion, catalyzing or promoting the miscibility of two or more liquids; drying and inoculation.

Some of these substances may remain in the colloidal fuel product in whole or part or having performed their set duty may be mostly distilled off and recovered and used again and again.

One of the advantages stated by Lucius H. Beers, chairman of the Submarine Defense Association, in a letter accompanying Mr. Bates' report, is that in making colloidal fuel great deposits of low grade coal, which have been largely unavailable, as well as vast quantities of lignites, brown coals and wasted dust, are added to the world's fuel supplies.

To drive the fleets of the air, the argosies of motor ships, the myriads of motor trucks and automobiles which will characterize this century, it will be necessary to employ all the resources of chemistry to provide from refining and distilling, enough of the light oils and spirit substitutes. The cracking processes of pressure-stills must be extended to all the crude and fuel oils that now we know. Colloidal fuels open the doors wide to let the world have from the stills all the essences it needs without starving the hungry boilers or the flaming furnaces of the grosser fluid fuels which constitute their food.

The report concludes:

"The demand for oil constantly augments. The oil measures of our earth-mother are being drained to dregs, increasingly as one field after another fails. Their history is always the same—the discovery, the feverish exploitation, the boom, the falter and the lingering death. The farms, the haciendas, the prairies, the jungles, the margins even of some seas, are yielding up their most precious possessions. The prodigal waste of oil is sin to be repaid in sorrow. Its conservation and guardianship is the task of those upon whom this world-solemn duty has been unprecedently laid. Ways have herein been made straight to do so with injury to none and helpfulness to all."

Concrete as a Chemical Engineering Material*

By Maximilian Toch

It may truly be said that this is the age of concrete. What progress would our new factories have made after this country went into war, when steel and iron were unobtainable, had it not been for the ability to use portland cement in its place? It is no criticism to say that portland cement concrete is an unfinished material when used in the erection of chemical works. No floor in any factory will last very long made of portland cement and sand, unless it is treated in some manner. I have seen instances where the concrete foundations of vinegar tanks were decomposed until they resembled a material like cheese, owing to the solvent action of acetic acid. I have seen foundations of motors and machinery where the oil drippings disintegrated concrete in a relatively short period. I could cite many more cases, but these will suffice. There are a great many materials which preserve portland cement construction against acids, alkalis, oil and saline solutions, and there is no one material which may be regarded as a panacea for all the defects of concrete. When the defects of concrete are mentioned I must again impress upon you that I am not criticising the material; but a concrete sidewalk is about the only cement construction of any magnitude that I can recall which needs no treatment to make it waterproof, wearproof and weatherproof.

*Address before the Am. Inst. Chem. Eng.

DEFECTS OF CONCRETE CONSTRUCTION.

Take the case of a concrete floor in a room where there is delicate machinery. In a short time the particles of sand and broken stone which form the composite of the concrete become loosened, float around in the air and lodge on the contact points of this delicate machinery. Take the case of foundations in chemical works, where acids and alkalis drip on the foundations. Take the case of concrete foundations of factory buildings on a waterfront, where niter cake and sludge acids are discharged in the stream, and you will soon erode the concrete foundations. All this is due to a very simple chemical problem. Portland cement has been described so often that I do not need to go into its chemical composition other than to say that when it is mixed with water it generates lime and the lime forms a glutinant material which binds the particles together. This same condition is identical in all mortars, and the common, ordinary lime mortar of building material, while it contains a much greater amount of lime than portland cement, is weaker in every respect than portland cement itself. Lime is slightly soluble in plain water and is relatively more soluble in salt water. This accounts for the disintegration of portland cement at the seashore. Any acid, no matter how weak, forms a chemical combination with lime; when the lime is attacked in portland cement the structure crumbles.

There are a large number of methods used for the protection and preservation of portland cement; and, as I have said before, there is no single method applicable in every case. Our Government and every other Government have had an enormous amount of trouble in building dry docks which would withstand sea water, even though some of these dry docks were faced with granite or other building stones, because the building stones must be cemented together with a mortar containing lime in some form. A very interesting case developed in one of the large dry docks in New York harbor, where the sea walls were waterproofed with an integral material but where the bottom was not waterproofed, and after a lapse of five years the solvent action of the salt water attacked the bottom, but left the sides untouched. But the greatest problem of all is the construction of foundations, vats and storage buildings for chemical materials which should be proof against acids and alkalis under normal conditions. Up to within two years ago no one ever thought of building storage warehouses of concrete for the storing of large quantities of niter cake. This material, as you know, is an acid sulphate of sodium containing as high as 30 per cent. of free sulphuric acid, and yet it has been possible to build successfully such a storage building which would house niter cake and not attack the walls and floors made of concrete. In a case like this it is necessary to use two methods—one, an integral method, and in addition to this, a surface coating which will be acidproof.

CONCRETE TANKS FOR STORAGE OF OIL.

The great scarcity of boiler plates for the building of large tanks forced our own Government to build tanks for the storage of fuel oil, of concrete; and, as there are two kinds of fuel oil—the very heavy Maltha, of the West Coast, and the thinner type of Pennsylvania and Ohio—it soon becomes obvious that the Maltha or Western type could be stored in any kind of a pit made of any material, but the Eastern oil would soon destroy the crystalline structure of portland cement and leak through. So it became essential to find methods of making concrete oilproof, and in this again the integral plus the surface coating method are essential.

To use a very homely comparison, and one that is somewhat graphic, I must frankly state that unless the engineer's specifications are strictly carried out, failure will inevitably result and no material should be blamed for a lack of supervision. To write a specification for concrete and chemical engineering construction is not an easy matter, and unless the inspector is intelligent and watchful, failure may result. I always think, in this connection, of the case of the man who went into a restaurant and called the waiter, and explained to him the kind of a steak that he wanted. He insisted that the steak should be an inch and a half thick and six or seven inches long, and it should be grilled over a coke fire for forty-five minutes at a distance of one foot from the fire; that after it was grilled it should be smothered with mushrooms and onions and then allowed to seep for ten minutes and placed on a hot plate and served to him. The waiter, after having carefully listened to these orders, walks over to the kitchen and yells "One steak." This is a very fair example of how many specifications are carried out and how engineering materials are blamed for the lack of carrying out the orders carefully.

Acid-Resisting Iron*

The History and Present Status of a British Contribution to Metallurgy

THE manufacturing chemist and metallurgist are greatly restricted by the limitations of applicability of their apparatus. In many processes, the difficulty is not so much to obtain the raw materials as to find furnaces, containers, pipes, &c., that will bear the chemical and physical stress of the reactions, and to avoid the contamination of the products by the substances with which the reactions bring them into contact. For these reasons many a promising process never gets beyond the laboratory stage; hence, also the cry for substitutes of rare, expensive materials, as well as the natural distrust of them. The enhanced activity of certain chemical industries has much increased the demand for refractory materials and acid-resisting alloys. Experiments with acid-resisting iron alloys are not new, of course. Wollaston made a silicon-iron, and he may not have been the first. Engineers and electricians found silicon-iron very useful for special purposes, and many attempts were made to construct chemical plant of silicon-iron and other iron alloys. Tungsten, chromium and nickel were tried. But foundrymen seemed to be unable to make vessels even of moderate dimensions of such materials, and it was not till 1912 that an acid-resisting iron alloy of sufficient uniformity and strength for the engineer to deal with was put on the market.

It was the tantiron of Mr. R. N. Lennox, made by the Lennox Foundry Company, of Glenville Grove, New Cross, S.E. Since then silicon-iron and other non-corrosive iron alloys have been brought out by several firms. Both the "duriron" of America and the "ironac," of Britain, are silicon-irons, like the Métillures of A. Jouve, one of the first in this field, and the Italian eleanites, which contain about 2 per cent. of nickel. "Ferrochrome" and "feralun" are likewise American products, and German activity in the field will not have ceased during the war; in addition to "neutraleisen" there are ferro-chromes and ferro-borons.

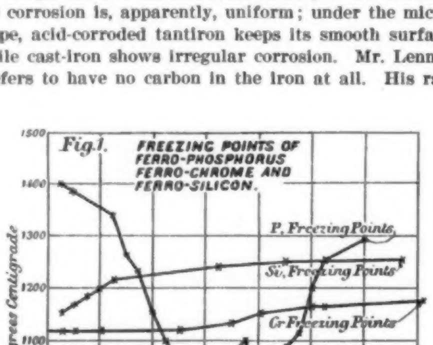
That Mr. Robert N. Lennox should have taken up the manufacture of apparatus for the concentration of strong acids was only natural. His father had made sulphuric acid in Glasgow in the days when heavy investments in platinum plant were indispensable for that purpose. When Mr. Lennox started a foundry on his own account, he had for a good many years conducted experimental engineering works of his own, and had, as assistant in the Royal Institution for nearly 25 years, taken his share in Sir James Dewar's low-temperature and high-pressure researches and in the manifold other investigations which are being carried on in the Royal Institution. Extensive well-equipped laboratories are a noteworthy feature of his works.

Tantiron—a fancy name—is a silicon-iron, containing about 15 per cent. of silicon. In appearance it is a silvery-white close-grained cast-iron, and has the general properties of a machinable cast-iron. One special brand of tantiron is very hard, and not machinable; another quality resists hydrochloric acid which the others do not. It melts at about 1,200 deg. C., can be cast, ground with carborundum, cut with the saw, drilled, screw-cut and tapped, &c. So far as chemical and mechanical corrosion is concerned, it is a superior iron and is used for cast vessels or in the shape of linings for those of steel or iron. It does not rust, except the skin, and the rust is removed by pickling in diluted sulphuric acid or by grinding. The tantiron itself is not—or practically not—attacked by sulphuric, nitric, or acetic acids, concentrated or diluted, boiling or cold, and indeed not by most chemicals. One kind already mentioned—a more recent invention—also resists hydrochloric acid equally well. Carbonic acid attacks it slightly, but the corrosion is only about one-thousandth that of cast-iron. Alkalis corrode it about as much as they do cast-iron; chlorates and perchlorates do not corrode it, and it will resist chlorine gas up to a temperature of 105 deg. C. But sulphur dioxide corrodes tantiron badly. In view of this latter fact, the suitability of tantiron pans and basins for the concentration of sulphuric acid is rather surprising. Large pans have been in use, however, we are informed, since 1912, and some 25,000 basins are actually in use in sulphuric acid works. There is some slight corrosion, of course, and there are breakages, partly due to the material, partly to improper treatment by unskilled labor, which causes many small and large accidents in these days of rapid plant erection and high-pressure activity. The maintenance cost of pans and basins is about 2½*d.* or 3*d.* per ton of acid concentrated. After boiling 100 grams of the alloy for 17 hours, 10 per cent. sulphuric acid was found to have dissolved 0.13 gram of tantiron, 25 per cent. nitric acid, 0.25 gram, and 30 per cent. hydrochloric acid, 0.16 gram.

*From *Engineering*, London.

The terms "non-corrodible and acid-resisting iron," are misleading, as all such general terms are. Every chemist knows that he must not allow metals to glow in his platinum crucible, as they would form fusible platinum alloys, and that caustic alkalis and certain alkali salts, and even the sooty flame of the gas burner, will ruin his crucible. Tantiron also has its peculiar weaknesses. It resists hot sulphuric acid much better than cold acid, and many instances of attack are so far inexplicable. In one case a tantiron tower containing vapors from boiling sulphuric acid showed defects in the top sections, without any attacks on the bottom sections. The top sections were replaced several times; the bottom sections, which had been in use for eighteen months, were taken out and inserted in the top, when they were attacked within a fortnight; yet temperature determinations at different points of the tower never showed differences exceeding 5 deg. C. In other cases, sulphuric acid, after being carefully freed from arsenic by sulphuretted hydrogen, attacked the tantiron nearly three times as quickly as the original acid. But the amount of attack is, of course, exceedingly small. A tantiron vessel weighing 4,950 grams, had 600 tons of sulphuric acid passed through it during concentration with a total loss of weight of 12 gram. The attack is mainly on the surface or skin, which should, therefore, be removed when corrosion tests are conducted.

Though the iron carbide seems chiefly to be attacked, the corrosion is, apparently, uniform; under the microscope, acid-corroded tantiron keeps its smooth surface, while cast-iron shows irregular corrosion. Mr. Lennox prefers to have no carbon in the iron at all. His raw



materials are cast-iron, scrap, and old tantiron, and further ferro-silicon. The latter is obtained with about 12 per cent. silicon from Middlesbrough, and in a 50 per cent. grade from Norway. The average composition of tantiron is in per cent.: silicon, 14 per cent. or 15 per cent.; total, carbon, from 0.20 per cent. to 0.60 per cent.; manganese, 0.25 per cent. to 0.35 per cent.; phosphorus, 0.16 per cent. to 0.20 per cent.; sulphur, under 0.05 per cent. The three kinds mentioned, machinable tantiron, hard tantiron and tantiron for hydrochloric acid, differ little in composition, but the small fractions of additional constituents are very important. To study their influence, ingots are poured from furnace charges of 1 ton, to which additions are made in very small increments; the ingots are then tested chemically and mechanically. The sulphur and manganese, in their percentages, seem to be of no consequence. The phosphorus, is deleterious, mainly probably because it is not uniformly distributed, but concentrated in spots. As phosphorus is added to iron, the freezing point is first lowered, and then, when 10 per cent. of phosphorus is exceeded, rises again, but the cooling curves are not regular, whilst the freezing point curves of silicon-iron and chrome-iron show a very slow, but steady rise with increasing percentages of those elements. Impact tests are made on ⅝-in. square bars, which are not noticed; they break, *e. g.*, under stresses of from 8 ft.-lb. to 10 ft.-lb., against 12 ft.-lb. to 14 ft.-lb. in the case of cast-iron. On the whole, the strength of tantiron is about 25 per cent. smaller than that of cast-iron. The following is a summary of the comparative properties of tantiron and cast-iron (the latter figures in brackets): Density, 6.8 to 7.0 (7.3); tensile strength, 6 to 7 (9 to 10) tons per sq. in.; transverse strength, bars of 12 in. by 1 in., 1,600 lb. (2,500 lb.); crushing strength per inch cube, 34 (40 tons); melting point, 1,200 (1,150) deg. C. hardness, 1.6 (1); heat conductivity, 8 (10); electrical resistance, 10 (8); resistance to corrosion, 1,000 (1); contraction allowance in casting, 3/16 (⅛) in per ft. As regards other properties, also of other materials, the comparative order for iron, tantiron, lead, quartz, stoneware is: Transmission of heat, 230, 215, 115, 28, 20; hardness, 24, 35, 1, 52, 32; density, 7.3, 7, 11.3, 2.6, 2.0; melting point, 1,150, 1,200, 335, 1,900, 1,800 deg. C.

With respect to corrosion by chemicals, there is generally a first attack, followed by relative immunity under continued exposure. The following figures indicate the percentage losses of tantiron after boiling for 24, 48, 72 hours; the greater action during the first 24 hours is largely due to the already-mentioned skin effect, the outer surface having been changed by contact with the sand in which the tantiron is cast; this skin is removed in the foundry, as we stated.

	First 24 Hours.	Second 24 Hours.	Third 24 Hours.
Sulphuric acid, 98 per cent.	·10	·02	·02
" " 30 per cent.	·07	·00	·00
Nitric acid, 1·4	·03	·01	·00
" 1·1	·01	·00	·00
Acetic acid, 60 per cent. ..	·03	·01	·00
Chromic acid, 10 per cent ..	·07	·00	·00
Tartaric acid, 25 per cent. ..	·06	·03	·03
Iodine (sat. sol.)	·00	·00	·00
Bromine water (sat.) ..	·01	·01	·00
Bleaching powder (sat. sol.)	·04	·01	·01
Copper sulphate (acid sol.) ..	·00	·00	·00
" " (alkaline) ..	·00	·00	·00
Ferric sulphate (sol.) ..	·06	·00	·00
Zinc chloride, 30 per cent. ..	·03	·00	·00
Ammonium chloride sol. ..	·05	·02	·01
Fused sulphur	·06	·01	·00
Fused nitrate of ammonia ..	·00	·	·00

To meet the peculiarities of the material, it is desirable that designers of parts to be made in tantiron should bear the following rules in mind: large flat surfaces should be avoided, corners be rounded; slots be used in preference to bolt holes; facing strips be narrow and of ample height; the effects of expansion and contraction should be well-considered; coreing and moulding be made easy, by preference without the use of chaplets to support cores. Among the chief products now made wholly or partly of tantiron, are: acid pans, basins, stills, bleachers, denitrating towers, autoclaves, condensers, pumps, stop cocks, valves, pipes and fittings, electrodes, &c. Frequently a tantiron lining will suffice to prevent either chemical or mechanical erosion. The largest tantiron casting so far constructed weighed 7½ tons.

The greatest care is bestowed upon clean moulding, which is mostly done by women, and use is made of rotating strickles in preparing the moulds for parts of circular section. For lining pipes with tantiron, the pipe must be suspended vertically by a flange with the core in proper position, the pipe to be lined being weighted below; if the liquid tantiron were poured into a horizontal pipe, the pipe would curve. This practice is generally adopted for lining iron or steel, wherever possible, and the part to be lined is well dried, but not pre-heated. The adhesion between the iron and the tantiron is said to be good, fusion taking place between the surfaces; the adhesion is tested with the aid of paraffin oil. The lining may have a thickness from ¼ in. up to 1¼ in. and more. The subsequent finishing of the product is largely done with the aid of carborundum wheels and grinders. It is rather curious that the fine tantiron particles torn off by the tools do not spark; there is only a glow. Drills, saws and planers are also used.

The basins for the heating and concentration of sulphuric are mostly of the plain porcelain dish style, but are provided both with a lip and an arc-shaped baffle; they are supplied also in the Webb and Dyson styles. The basins are arranged in cascade, so that the hot acid drips from the lips of one basin into the one next below, and the baffle prevents the acid from streaming right over the basins to the lip. Provision for more efficient circulation and stirring of the acid in the basin is made in the "Mackenzie field tube evaporator basins," this style has calix shape, being a tube opening out into a basin; a "field" tube fits concentrically into the cylindrical portion and promotes active circulation. Other basins are provided with covers and necks, and made corrugated, and they serve generally also for the concentration of corrosive liquids, such as zinc chloride, lead nitrate, &c.

The concentration of nitric acid requires more varied apparatus, which have successfully been made of stone-

ware in the past few decades. When the war broke out, the stoneware works of this country were not able to deal with the demands, and tantiron vessels, which can be made in a few days, while good stoneware requires months, were largely adopted. Valentiner plants comprising, a still, condenser and coils, built up of pipes and return bends flanged together, all of tantiron, are now made. The denitrating tower is an interesting novelty. The spent acid of nitroglycerin works consists of diluted sulphuric acid, which has to be concentrated again, and some nitric acid, which is to be regained by distillation. There may also be small globules of oily nitroglycerin which might coalesce if the evaporation were carried on in pans. The tower, 15 ft. high, is built up of socket pipes, 14 in. diameter, and is packed with quartz fragments; the acid enters at the top and steam at the bottom, and the nitric acid and vapors condense in the cylinder by the side of the tower. Nitric-acid stills are also used for the distillation of acetic acid. The autoclaves for making ammonium nitrate from cyanamide at a temperature of 120 deg. C. and a pressure of about 2 atmospheres, resemble one style of nitric-acid retorts. The outer vessel is a jacket of cast iron, the inner vessel of tantiron forms the saturator; the height is 8½ ft., and the diameter 4½ ft.

Acid eggs, apparatus for forcing up corrosive liquids with the aid of compressed air, are made of two tantiron cups, joined by their top flanges so as to form a horizontal cylinder with spherical ends and one common flange; on the vertical middle plane they are provided with acid inlet and outlet valves and an air pipe, and are supplied in large sizes. The pumps of the works, reciprocating and centrifugal, do not differ much in appearance from ordinary pumps; the barrels and impellers and pipes are made of tantiron or lined with it. As these parts of hard tantiron cannot be machined or repaired, it is recommended to keep spare parts ready for cases of accident. Centrifugal pumps are supplied for lifting 6,000 gals. of acid or corrosive mine water, &c., per hour, against a head of 50 ft., running at 1,600 r.p.m. Slime pumps, *e. g.*, for conveying the crushed quartz in gold mines are likewise made of tantiron, to obviate the heavy erosion of the pipes by the gritty quartz particles. For the same reason, tantiron-lined steel pipes are used in the Rand mines, South Africa, for the sand-filling plant. When the pillars left in the galleries below are to be removed, the galleris have to be refilled with the finely crushed quartz from the vast white waste mounds which form a conspicuous feature of the district. The spoil is flushed down the pipes with water. The first pipes used, steel pipes, were ruined by 6,000 tons of sand; porcelain-lined pipes were then tried, which could stand up to 50,000 tons; the tantiron pipes, introduced four years ago, are still doing duty, and their life capacity is estimated at 500,000 tons. The erosion is greater at the top, where the sand strikes the pipe than at the bottom, and is not the same in all sections, probably owing to peculiarities of their positions. Similarly-lined steel pipes and tantiron pipes, up to 2 ft. in diameter are in use for ash ejectors, especially on board ship, where heavy erosion and corrosion by the caustic ashes and the sea water have to be guarded against.

In stop cocks and valves of tantiron corrosion by acid sodium bisulphate (the acid cake residue of the distillation of nitric acid from salt and sulphuric acid), erosion by grit, rusting and sticking are the chief sources of trouble to be met. Here, again, tantiron competes with lead and stoneware, and its advantages lie in greater strength and indifference to high temperatures and frost. A groove is made in the center of the cock and charged with a greasy preparation of ceresin, vaseline, black lead, and asbestos, which is pressed into the groove by means of a screw. A great variety of cocks, valves, T-pieces, straight and bent socketed pipes, provided with threads, are made in tantiron.

Of other specialties, we mention the corrosive-vapor drying and baking ovens, the flat doors and walls of which are lined with sheets of tantiron, which are screwed on. Tantiron can be rolled at about 700 deg. C., but is brittle then. Another specialty is the tantiron electrode for cyanide baths (silver and gold), and also copper baths, &c., replacing iron and other alloy electrodes, which are not insoluble, and very objectionable on this account, or more expensive than tantiron. For the same reason, steel-mixing mills for the manufacture of manganates, the balls and stirrers of other mills, and many aparatus used in the acid and dye and other chemical industries, are made of tantiron.

Like every other manufactured article, tantiron is constantly being improved, and does not claim to have reached final perfection. Acid-resisting materials must possess various properties which are not easily combined, and possibly not capable of combination. A compromise has to be accepted.

The Influence of Aviation Upon Mathematical Physics

A DIRECTION in which much work is now being done is in the dynamics of and through media. This is an immediate effect of the development of the art of flying. In order to achieve success in aeronautics two problems referring to our subject need investigation—motion through a resisting medium and meteorology. The war has reacted profoundly upon this phase of research. Whereas only a few years ago orthodox mathematicians stood more or less aloof from aeronautical mathematics, the case is quite different now. The successful vindication of the researches of Lanchester and Bryan as leading to criteria of stability and controllability of an aeroplane based on exact mathematical formulation, and the imperative necessity to apply the best brains of the country to the solution of the urgent problems of aircraft attack and anti-aircraft defence, have swept away the the remains of old prejudice. It is obvious, of course, that much of the work that has been and is being done during the war must remain unpublished, and there can be no doubt that the cessation of hostilities will be followed by the release of an amount of accumulated knowledge and results that will color the teaching and development of dynamics for many years. Nevertheless, a considerable amount of important work, that has no immediate bearing upon practical military problems, is being published. Among the recent researches that have come to the notice of the writer are the following:

P. Appell (*Comptes Rendus*, 165, 694-5, 1917; 166, 22-3, 1918) discusses the results of experiments made by Z. Carrière (*Jour. de Phys.* 175-86, 1916) on the two-dimensional motion of a light sphere moving in air under gravity, having a rotation about a horizontal axis perpendicular to the plane of motion. Carrière found that after an initial part dependent on the initial conditions, the motion becomes practically uniform in a straight line inclined to the downward vertical in the same sense as the rotation, the inclination increasing with the ratio of the rotation to the translational motion. Appell suggests that the motion can be explained if the air resistance is taken to act in a line through the centre of the sphere, making an angle with the backward direction of motion dependent on the angular velocity, and states that he intends to publish the mathematical analysis for the assumption that the air-resistance varies as the velocity. In a paper read at the Royal Society but not yet published (*Nature*, 483, 1917), the writer of these notes shows that the centre of a plane lamina moving in two dimensions in air, the law of resistance being the square of the velocity, moves in a manner similar to that found by Carrière for a light sphere. One may even suggest that probably any rigid body moving in air under gravity will after a time approximate to a type of "terminal" motion along a wavy line inclined to the vertical in a sense and to an extent dependent on the relation between the rotational and the translational velocities. It is well known that a particle tends towards a terminal motion in a vertical straight line.

H. Larose (*Comptes Rendus*, 545-8, 1917) investigates the steady motion of a uniform flexible and inextensible string in air under gravity, finding the equations of the various forms of a string moving with a constant velocity along itself and an additional velocity in a horizontal direction.

Another problem in resisted motion is worked out by J. Prescott in a paper entitled "On the Motion of a Spinning Projectile" (*Phil. Mag.* (6), 332-80, 1917). The author takes the air resistance to be proportional to the square of the velocity, the constant of proportionality being one or another according as the velocity is less than or greater than 1,060 ft. per sec., thus introducing an important modification into the method of Bashforth, who made the resistance vary as the cube of the velocity, the constant of proportionality varying as the velocity underwent any considerable change. Assuming first that the resistance is always exactly opposite to the direction of flight, and then introducing the effect of the shape of the projectile by supposing the resistance to act in the plane of the axis of symmetry and of the direction of motion, at an angle with the former some constant times the inclination of the latter, Prescott calculates the trajectory as well as the drift and the angular defection of the axis of the projectile.

P. Frank (*Phys. Zeitschr.*, 2-4, 1918) shows that the problem of steering an airship in a variable wind so as to go from one point to another in minimum time leads to an equation of the same type as occurs in the propagation of light in a moving medium.

J. G. Leathem (*Phil. Mag.* (6), 119-30, 1918) continues his work on curve factors in the conformal representation of hydrodynamical problems in two dimensions (see also *Phil. Trans.*, A, 439-87, 1915, and *Proc. Roy. Irish Acad.*, A, 35-57, 1916). The fact that the lifting power of an aeroplane is greatly improved if the wing is not flat but "cambered," so as to be slightly concave on the lower surface and considerably convex on the upper surface, has long been made use of in practical aeronautics. On the other hand the investigation of the discontinuous stream-line motion past such a wing has long defied analysis. Thus Greenhill in his report on the subject to the Advisory Committee on Aeronautics (Report 19), published as recently as 1910, limits himself explicitly to plane barriers, or combinations of plane barriers. H. Levy (*Proc. Roy. Soc.*, A, 285-304, 1916) showed how to extend the classical work of Kirchhof and Rayleigh to curved boundaries. Leathem's method consists in discovering conformal transformations applicable to curves by extension of and analogy with known cases.

The practical problem of finding the resistance to motion through a medium is, however, best solved experimentally, and the work of Eifel, Dines, Bairstow and others has been mainly instrumental in supplying the information upon which the successful conquest of the air has been based. The hydrodynamical calculations are bound to lose in practical value because of the abstract nature of the problem when simplified into something that can be attacked by present mathematical analysis, since viscosity has to be omitted in general. We must wait till we learn more concerning the nature of the viscous forces in simple types of motion in a gas or liquid. We note that Guillet (*Comptes Rendus*, 33-5, 1918) has investigated experimentally the viscosity couple in the case of a lamina endowed with oscillatory rotation in its own plane.—*Science Progress.*

The Sizes of Cells

W. BROTHERTON and H. H. Bartlett have studied the variation of the size of the epidermal cells from the stems of Phaseolus (*American Journal of Botany*, April, 1918) in light and darkness. They emphasize the importance of comparing those cells which occupy corresponding positions on the curves of variation. The work of G. Kraus and MacDougal has shown that in etiolated plants the increased length of the internodes is mainly a result of an increase in the length of the cell units, though in part an outcome of their larger number. The present authors find that under constant conditions variation in length of the internodes appears to be associated mainly with an increase in the number of cells. The effect of light is regarded as directly or indirectly to retard cell division. There is apparently a physiological limit to the size which a primary cell can attain without undergoing division. In each internode there was an increase in the size of the cells from the base upwards till a maximum was reached followed by a diminution, at the top of the internode, which however was not so great as at the base.—*Science Progress.*

Artificial Gravel

IN one of the Southern concrete shipbuilding yards all conditions were favorable except that there was no rock or gravel at hand, and concrete is not to be made without it. Sand was there in abundance and so was clay, but mud ships have not yet been accepted as reliable carriers on the deep seas.

Clay is curious stuff. Chemically speaking it is a mixture of hydrated aluminum silicates with impurities in great variety. Its geologic history, however, is often more important than its exact chemical composition, for the conditions under which it has existed for the preceding hundred thousand years or so have a great bearing upon the size and structure of its particles; and in practice the physical nature of the particles of a substance has a great deal to do with its chemical behavior. The children of Israel needed straw to make brick, not that the straw fibre should serve as a binder, but because of a colloidal substance contained in straw which caused the particles of defective clay to bake into first quality product. It was a mean trick of the Egyptians to withhold straw and it was bad manufacturing practice, too.

Research with the Southern clay showed that if it is fixed at the proper rate and temperature very hard and porous lumps of the desired size result. Concrete made with them has practically the same crushing strength as that made with crushed rock. So proper apparatus was installed and the product used as aggregate. Owing to its porous nature it is very light, but the completed ships stood up to all the tests and proved to have a carrying capacity compared to dead weight clear above that of wooden or other concrete ships and nearly equal to those built of steel. A standardized contractor without the aid of a good chemist would have moved the yards or imported gravel.—*Little Journal.*

The Influence of Astronomy on Human Thought*

The Study of the Universe in its Rôle as the Science of Infinite Space and Infinite Time

By Rev. Hector Macpherson

Astronomers are sometimes called "star-gazers"; and the word, though often playfully applied, has in it a certain suggestion of pity, if not of contempt. It is usually applied by those who know just enough of astronomy to know that there is in its cultivation an unworldly and idealistic motive, and too little of the science to realize its great practical and intellectual benefits,—indeed, its necessity to the human race.

Those of us who have studied and followed the science realize that it is by means of astronomy that latitudes and longitudes are determined, and extensive navigation made possible,—that it is by means of astronomy that land-surveys can be carried out and accurate time determined. These are the most obvious practical uses of the oldest of the sciences.

"The student of astronomy," the late Professor Young once remarked, "must expect his chief profit to be intellectual—in the widening of the range of thought and conception." There is a danger, in emphasizing the practical necessity of astronomy to the world, of forgetting the part played by astronomical science in the development and progress of human thought—on the world on which we live and the universe of which it forms a part. It is to the influence of astronomy on human thought that I desire to direct your attention this evening.

It is a wide subject, and in dealing with so wide a subject, it is necessary to be as concise and definite as possible. So I shall deal with the subject in two parts, which may be roughly classified as (1) cosmological, and (2) cosmogonic. An American scientist in a popular work used the phrases, "the extension of the Universe in space," and "the extension of the Universe in time." I shall take these phrases to designate the two parts of my lecture.

THE EXTENSION OF THE UNIVERSE IN SPACE.

From the earliest times, the human mind has been confronted by the great problems presented by the natural world. The name of the first actual students of nature must remain forever in obscurity. It is tolerably clear, nevertheless, that astronomy is the oldest branch of science, because the heavenly bodies are the most prominent of natural objects. The early observers of nature must have noticed the phases of the moon and the changing aspect of the starry skies, and later, the fact that the sun varies in its altitude above the horizon.

In all probability, this kind of knowledge grew up simultaneously among various peoples. There are traditions of early astronomers and astrologers in China, in India, and in Egypt and in Babylon, for early astronomy was inextricably mixed up with astrology and religious ceremonial, and thus the priests of the ancient religions were in many cases the pioneers of astronomical observation.

An intelligent study of nature is almost invariably accompanied by what is called a cosmology or world-concept. The mind of man, even in primitive conditions, is not content with knowing things as they seem to be; it desires to know things as they are, and to penetrate behind the veil of appearances. The human mind ever seeks a world-concept. Thus, even in very primitive times, men formulated theories of the natural order and of the relation of the earth, our dwelling place, to the outside world as a whole.

Every ancient people had its cosmology or concept of the order of the world, and accompanying this, its cosmogony, or theory of the world's origin. That these early ideas were crude and fantastic is not to be wondered at. The late Professor Pfleiderer pointed out that among early peoples "cosmogony is at the same time theogony," and we might also say that cosmology is at the same time theology. To the early peoples, nature was full of deities, gods of land and of sea, of sun and stars, of storm and tempest. Both religion and science were born of a crude cosmo-theology,—largely the product of wonder and fear.

The early races, Chinese, Hindus, Egyptians, and Babylonians, seem to have made considerable progress in astronomical observation, but they never got beyond this confusion of theology and science. Many of the empirical facts of astronomy were noted and recorded by them. The five planets were known to these races, and the paths of sun and moon laid down. In short, a large number of interesting facts were ascertained, but there the achievement ended. There were world-concepts in plenty, but these world-concepts were not the result of observation. They were guesses at the riddle of the universe, a jumble of pagan theology and astrological superstition. The Hebrews and the Greeks were, in the things of the spirit, the greatest races of antiquity and to them fell the task of separating religion from science. The Hebrews, who had little or no interest in natural science, disentangled religion from crude naturalism and pseudo-science, while the Greeks were the founders of actual scientific observation, and based their theories on actual fact.

Of course, it is impossible to draw hard and fast lines between various races. The transition from the pseudo-science of the Babylonians to the careful observation of the later Greeks was a gradual one. Thus Homer and Hesiod give us some idea of the similarity of the early Greek ideas of the world to those of the Babylonians and other ancient peoples. And the Ionian school of philosophers, important and sagacious as were their theories and guesses, still followed a deductive method. They framed theories with little or no observations of natural phenomena. And so even in the period of the greatest triumphs of Ancient Greece, we cannot truthfully talk of the influence of astronomy on human thought. The influence was slight, for thought was *a priori* and theories were deductive.

With Eudoxus of Cnidus, the cosmology of the Greeks entered on a new phase. With all his limitations, Eudoxus may be described as the first investigator of cosmological problems from a purely scientific standpoint. The earlier philosophers had proceeded on the ground of reason alone. Their method[1] was deductive. Eudoxus, on the other hand was an inductive thinker. First and foremost he was an observer of the phenomena of the heavens, and, to explain these phenomena, he advanced his famous theory of homocentric spheres. Whether the theory was ever more to him than a convenient working hypothesis is uncertain. Dr. Dreyer, who has made a close study of the Eudoxian theory, believed that Eudoxus only regarded his spheres as "geometrical constructions suitable for computing the apparent paths of the planets." Be this as it may, the theory, complicated and cumbersome as it was, accounted fairly well for the observed celestial motions. If there is a possibility that the theory was merely a theory to Eudoxus and his pupil Calippus, who improved and extended it, it was a great deal more to Aristotle. In fact, it formed the basis of that great philosopher's world-concept, and in estimating the influence of astronomy on human thought, it must not be forgotten that the astronomy of the day formed the scientific basis of the theory of man and the universe which held sway for so many decades and centuries over the human intellect. To Aristotle, the spheres were actually in existence, portions of the vast mechanism of the universe. He found it necessary to add twenty-two extra spheres. Calippus had assumed the existence of thirty-three, so that, as left by Aristotle, the system comprised fifty-five separate spheres. Aristotle as we all know, adopted the belief in the spherical form of the earth, and gave to it the weight of his great authority.

It is somewhat remarkable that while more and more stress came to be laid in philosophical and speculative circles on Aristotle's opinion as to immobility of the earth, the astronomical theory on which he based his hypothesis,—the spheres of Eudoxus,—was soon discarded. The progress of practical astronomy, by demonstrating its inadequacy, hastened its rejection. The necessity of regulating time, the need for an accurate calendar, had stimulated observation of the sun and moon, and this in turn influenced other branches of astronomy. At Alexandria, under the patronage of the dynasty of the Ptolemies, a school of astronomy was founded, and systematic observation of the heavenly bodies was made. As Dr. Dreyer has well remarked, "Vague doctrines and generalizations were abandoned, while mathematical reasoning founded on observation took their place. That this change occurred about the middle of the third century (B. C.) was a circumstance not unconnected with the simultaneous rise of the school of Stoic philosophy. Both in abstract philosophy and in science, the wish to get on more solid ground now became universal, and no science benefited more by this realistic tendency than astronomy."

To Apollonius of Perge is due the distinction of inventing the famous theory of epicycles, which superseded the hypothesis of Eudoxus. The idea of concentric spheres was abandoned. Sun, moon, and stars were assumed to be in motion round the earth in circular orbits. But some explanation had to be given of the irregularities of the celestial motions. In essence, the systems of Apollonius, Hipparchus, and Ptolemy were identical, but the latter worked the epicycle theory to its fullest perfection. Thus the astronomy of the day gave credence to the belief that the earth was the center of the universe, and man the crown of creation.

Ptolemy was the last great name in ancient astronomy. In his great work, the "Syntaxis," which came to be known by its Arabic name of the "Almagest," were summed up the results of the ancient Greek astronomy. There was an air of finality about his great book. He was himself the last great astronomer, for the great days of science seemed to be at an end. The Hellenic culture had largely exhausted itself; an air of hopelessness and futility had settled over the world, and the Stoics rather concerned themselves with problems of conduct than with questions concerning the natural world; while the early Christians, expecting the early return of Christ, did not busy themselves with the affairs of this world. Accordingly, slowly but surely, science and philosophy alike seemed to die out. When the Emperor Justinian suppressed the Neoplatonist Schools in 529, he merely gave legal expressions to an accomplished fact. The long night of the so-called "dark ages" had begun.

As the church grew more and more powerful, as it became gradually not so much the Christian Church as the Church of Rome, the Ptolemaic world-view was stamped with the approval of ecclesiastical authority. And so, for hundreds of years, this remarkable system held sway over the minds of men, and was used to support and demonstrate the Roman Catholic view of life.

THE COPERNICAN REVOLUTION.

With the coming of the Renaissance, the minds of men were once more turned to intellectual things. A number of men of scientific tastes arose,—such as Nicholas of Cusa, Purbach and Muller, better known as Regiomontanus. These men, however, remained faithful to the orthodox Ptolemaic theory. And when the famous system of Copernicus was first propounded, it came on the world as a bolt from the blue. It is difficult for us of today to realize the magnitude of the scientific revolution which Copernicus initiated. From time immemorial, all,—except, perhaps, a few irresponsible thinkers among the Greeks, such as Hicetas and Aristarchus, whose names were unknown save to the learned few,—had believed the earth to be the center of the universe, the end and aim of creation. Only the earth was inhabited, and for the earth's inhabitants the other bodies in the universe had been created,—the sun to give light and heat to the earth, and the moon and stars to be convenient secondary light-givers in the absence of the sun. This conception had been taken up by the Roman Church, and by the Scholastic philosophy. Little wonder, then, that the appearance of the great work of Copernicus in 1573 caused no small stir. At first, it was treated by the authorities with contempt, and then with furious vindictiveness. Copernicus himself was beyond the reach of popes and priests, for he survived only until the day of the publication of his great work. It soon became apparent, however, that he was but a voice crying in the wilderness. When Copernicus died, the Reformation struggle was at its fiercest. Yet Protestants vied with Roman Catholics in denouncing a theory which they felt to be subversive to the true faith. Luther referred to Copernicus as "an upstart astrologer, who strove to show that the earth revolves." "This book," he continues, "wishes to reverse the entire science of astronomy, but sacred scripture tells us that Joshua commanded the Sun to stand still, and not the Earth." Melancthon went so far as to suggest the forcible repression of such views. The struggle became fiercer and fiercer. The advocacy of the new view was one of the charges on which Bruno was condemned to death and burned at the stake in Rome in 1600. The second "martyr" of the Jesuits was harassed and persecuted solely for his adhesion to the Copernican system. Indeed, it was in the course of the contest between Galileo and the Papal authorities that Copernicanism was finally condemned. We are all familiar with the story of the struggle, how Galileo discovered the spots

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*Read before the British Astronomical Association, West of Scotland Branch. Reproduced from *Popular Astronomy*.

[1] A Parmenides it is true, had guessed the great truth of the spherical form of the earth and this was accepted by Eudoxus.

on the sun, the satellites of Jupiter, and the phases of Venus, thus weakening the Ptolemaic system and confirming the Copernican. Each of these new discoveries was doubted, disbelieved, and minimized. But with all their furious bigotry, some of these Roman theologians saw clearly the essential influence of the Copernican system on human thought. After all, the vital point of the new doctrine was not an increased number of celestial bodies or the existence of mountains in the moon and spots in the sun. It was the fact that the earth was no longer the centre of the universe. Grant the truth of the Copernican system, and the whole outlook on the universe is changed. As the earth is no longer the only world, so man's supremacy becomes less certain. Boundless possibilities are opened up. The greatness of Copernicus is not to be measured by what he did, but by what he made possible. A vast extension of the universe was revealed; and so the philosophic and theological outlook was vitally affected by the new system. While the Scholastics were still vainly trying to refute Copernicanism, and the theologians were engaged in hurling anathemas at the heads of its supporters, the new system of the world was being established on a firm theoretical basis.

THE NEWTONIAN SYSTEM.

Tycho Brahe was no great constructive thinker; he contributed little to the actual cosmological conception of the time,—for while he abandoned the Ptolemaic theory, he could not adopt the Copernican, and found refuge in a half-way house known to posterity as the Tychonic system, which, while conceding the motion of the other planets round the sun, preserved the immobility of our world. But Tycho was one of the most industrious collectors of data whom this world has ever seen, and from the data collected by him the new system of the world was to be finally confirmed. After his exile from Denmark, he became acquainted with Kepler, who came into possession of Tycho's huge mass of observations when the latter died. By means of these,—the most perfect hitherto made,—Kepler sought to discover (1) how the planets revolved round the sun, and (2) why they revolve. He was successful in his first quest, and the three empirical "laws" of planetary motion are the monument of his labors. He failed in his second quest. The force controlling the planetary motions he believed to have its origin in the sun. But he was unable to reach any definite conclusion, and it was reserved for Newton to enunciate the law of gravitation, which made intelligible the empirical laws of Kepler. The importance of Newton's great work cannot be overrated. Laplace declared that the "Principia has a pre-eminence over all productions of the human intellect."

The Newtonian theory not only profoundly influenced astronomy and shaped its whole future course; it profoundly affected all human thought. In the first place, Newton demonstrated the simplicity and unity of the known universe. The old idea of a radical difference between things celestial and things terrestrial,—already seriously damaged by the observations of Tycho Brahe and Galileo,—was now definitely refuted. The whole planetary system was seen to be ruled by one law. In the second place, as Hoffding has truly remarked, "It was now clear that the fixed and law-abiding order of Nature prevails not only here on this Earth but also throughout the Universe." The world was now seen to be a huge machine. The scientific doctrine of the uniformity of nature, of which so much has been heard in philosophy and scientific thought, was now definitely established. In the third place, the era of the mechanical conception had dawned: and this mechanical conception had an abiding influence over human thought. Hoffding has pointed out the remarkable connection between Newton's religious conceptions and his doctrine of mathematical physics,—a connection which arose through his concept of space as the organ by means of which God works as omnipotent in the world.

Newton proceeds to prove, from the purpose and order in the world, the existence of God. The world is a great machine, set in motion by God, Who by supernatural means has arranged the masses, distances and velocities of the planets; but the interference of God is required from time to time, owing to the irregularities arising from the actions of the varous bodies on one another,—an idea which drew from Leibnitz the criticism that Newton had compared the universe to a clock, which required the constant interference of the watchmaker.

Deism in the religious sphere conceived of God as external to His works; and the Newtonian cosmology in the hands of Newton, and more particularly of his distinguished successors and the popularizers of his system, inevitably regarded the Creator in a similar light. Men such as Ferguson, and even Paley himself, never got beyond the idea of the world-system as a great mechanism. As Ferguson remarked,—"That the projectile force was at first given by the Deity is evident." Men such as Ferguson, Paley, and Thomas Dick would have been the first to repudiate the charge of Deism, and rightly so. Yet the mechanistic conception of the universe, prevalent in the eighteenth century, had a profound influence on higher thought, inasmuch as it prepared the way for Deism and commended it to the rational faculties. In the writings of the popularizers of Newton, we find a constant emphasis on design, contrivance and impelling power. There was a latent Deism in this cosmological concept, as is obvious from the remark commonly credited to Laplace,—"I have no need of the hypothesis of God."

HERSCHEL AND HIS WORK.

The rise of the elder Herschel marked another great epoch in astronomical history. Astronomy had apparently settled down in fairly conventional lines. One of the beneficial results of Newton's great work in science was the concentration of the minds of astronomers on the great task of the verification of the law of gravitation. Astronomical observation had for its end and aim the confirmation and perfection of the Newtonian theory, and so attention was directed chiefly to the bodies of the solar system, their motions and mutual perturbations. The stars were observed principally as convenient reference-points by which the positions of the moon and planets could be accurately fixed. In the course of these observations, several facts, it is true, were ascertained. Thus in 1718 Halley noticed that the stars Sirius, Aldebaran, Betelgeuse, and Arcturus had perceptibly moved since the formation of the Ptolmaic catalogue. Efforts too were made to measure the distances of the brighter stars. In addition, isolated thinkers, Kant and Lambert in Germany, and Wright and Michell in England, speculated on the structure of the sidereal universe, and some marvellous intuitions were reached. But there were no data on which to base a theory of the cosmos external to our solar system.

This was the state of affairs when William Herschel appeared on the scene. He was not a great mathematician, and his work lay in the direction of making observations and systematizing the results which he derived from them.

Herschel's contributions to cosmological thought may be summed up under these heads: (1) He demonstrated, what other observers and writers had believed to be probable, the essential kinship of the sun with the stars. In his bold and masterly paper contributed to the Royal Society of London in 1783, Herschel, making use of the proper motions of seven stars and separating what he believed to be their real from their apparent motions, reached the conclusion that the sun, carrying with it the planets and satellites, was moving towards a point in the heavens near to the star Lambda Herculis. Copernicus had shown that the earth, so far from being the center of the universe, was but one planet among others in ceaseless revolution round the sun. Herschel now proved that the sun itself was not the central body, but was merely one star among others in ceaseless motion through the depths of space.

(2) Herschel's investigations of double stars led him to the conclusion that the law of gravitation held sway throughout the depths of space. Newton had shown that the law ruled in the solar system, and his successors demonstrated that that law explained nearly all the irregularities of the planetary motions. From analogy it might have been supposed that the same law ruled the system of the stars, but there was no proof. When Herschel demonstrated that several double stars were in revolution round their common centre of gravity, he supplied the proof.

(3) Herschel's long-continued series of studies on the construction of the heavens did not result, it is true, in the solution of that problem.

The famous disc-theory was put forward only to be abandoned, and when Herschel died, he left the problem further from solution than ever. But his researches did prove that the sidereal heavens constituted a greater system, of which the solar system formed part. And Herschel's researches demonstrated also the vast scale on which the universe was built. His theory that star-clusters and nebulæ formed universes external to our Galaxy implied an immense extension of the universe in space and time. In conversation with the poet Campbell in extreme old age, Herschel said truly, "I have looked further into space than ever human being did before me," adding more hypothetically, "I have observed stars, of which the light, it can be proved, must take two millions of years to reach this earth." The stupendous vistas opened up by Herschel's work had an enormous influence on contemporary thought. As Horace Walpole expressed it,—"One's imagination cracks." Herschel's epitaph in the churchyard of Upton, near Windsor, claims that "he broke through the barriers of the skies." It is no exaggeration to say that this is true. He revealed to mankind a universe of almost inconceivable vastness, ruled over by the law of gravitation. Compared to the extension of the universe in space which we owe to Herschel and his immediate successors, the Copernican revolution seems a very small affair.

THE EXTENSION OF THE UNIVERSE IN TIME.

This was by no means the sum of Herschel's work in astronomy, not only did he reveal greater vistas in space, he likewise had a share in the development of cosmogony.

Every ancient cosmology included a cosmogony. The early Greek thinkers undertoook to explain not only the construction of the world, but also its origin. With the rise of a school of exact science, cosmology and cosmogony parted company. Hipparchus and his successors did not concern themselves with the origin of things, and so the idea of evolution or development which had made its appearance in the guesses of the Ionian philosophers was almost forgotten. After the conversion of the Roman world to Christianity, the Hebrew cosmogony contained in the first chapter of Genesis was accepted throughout Christendom as the final word in the method of creation. The theory of six literal days of Creation and a "carpenter God" was accepted without question for hundreds of years.

Curiously enough, it was a theologian, Ralph Cudworth, who in 1678, in his "Intellectual System of the Universe," argued against the prevalent mechanical theory of a literal and finished creation, and in favor of development in accordance with an immanent principle. In the eighteenth century our illustrious Scottish astronomer, James Ferguson, threw out a remarkable hint as to the building-up of the solar system as a result of gravitational action. "In the beginning," he said, "God brought all the particles of matter into being in those parts of open space where the sun and planets were to be formed, and endowed each particle with an attractive power, by which these neighboring and at first detached particles would in time come together in their respective parts of space, and would form the different bodies of the solar system."

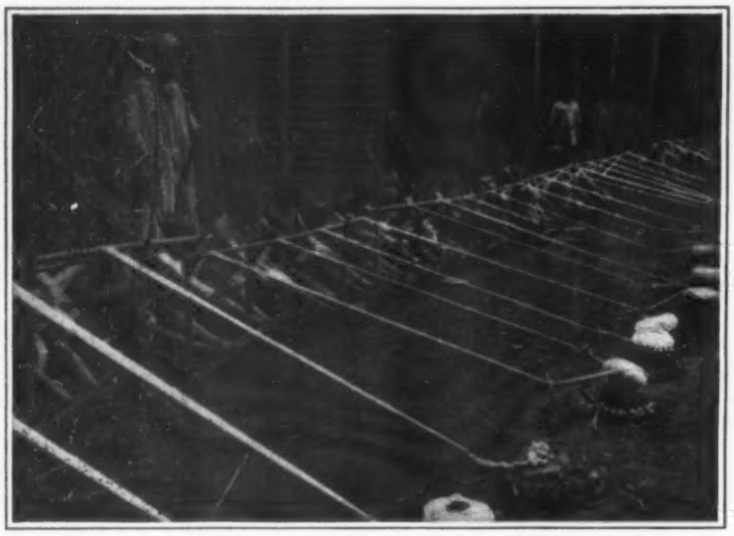
The nebular hypothesis, as we know it, originated independently in the minds of three men,—Kant, Laplace, and Herschel. Neither Laplace nor Herschel seems to have been acquainted with Kant's speculation or with the views of each other. Kant and Laplace proceeded on the deductive method. Their theories were pure speculations. Herschel was led by his observations of nebulæ and nebulous stars to postulate the gradual development of nebulæ into stars and planets. Laplace had declared that at one time the solar system had been in a nebulous or gaseous state. Herschel pointed out that such gaseous masses were actually in existence in the heavens, in all stages of evolution.

At first the nebular theory was received with indifference. Laplace had promulgated his view, diffidently, in the appendix of a popular book. Herschel published no books, and his gradually developing views were only to be understood by a study of his papers in the "Philosophical Transactions" of the Royal Society. Gradually the indifference died away. Theological writers and scholars opposed the theory bitterly, but there was also a scientific opposition, for the average scientist of the time was still at the stage of the mechanical conception of nature.

Slowly but surely the mechanical theory was passing away. Even in theology Deism was giving place to the new sense, which we find in Coleridge and Schleiermacher, of the Divine immanence; in philosophy the empiricism of the French school was giving way before the idealism of Fichte, Schelling, Hegel, and Goethe; and in physics the whole mechanical concept of empty space and isolated bodies was disappearing. In 1801 Thomas Young revived the wave theory of light, which assumed the existence of a luminiferous ether. Each of these developments had its effect upon human thought. The contribution of astronomy was the work of Herschel and Laplace in showing the possibility that the celestial bodies had arrived at their present condition in obedience to a process of evolution. Thus, astronomical science, no less than geological, enormously extended the period during which the universe had been known to exist.

Herschel's discovery of the solar motion had shown the sun to be in every respect similar to the other stars. His investigations of the construction of the heavens had shown that the stars actually formed a connected system. The new theory of light, by destroying the conception of empty space, assumed the unity of the

(Continued on page 352)



Native cotton-weaving workshop at Fumban

Fumban women weaving splint baskets

Some Native Industries of German Cameroon

The Character and Nature of the West Coast Bantu from the European Standpoint

(All Photographs copyrighted by the Press Illustrating Service)

RECENT changes in Africa have attracted attention to the rather populous district embracing about 190,000 square miles on the western equatorial coast of Africa formerly known as German Kamerun. This province which is about the size of Germany and supports a total population of about 3,500,000 souls (1,128 whites included), lies between the French Congo on the east, Lake Tchad and Nigeria on the north and northeast, and the Atlantic coast of equatorial Africa on the west. Lying between latitude 2° and 12° N., its climate is true equatorial, characterized by a very uniform temperature throughout the year, a very heavy rainfall—indeed at two points the fall is next to the heaviest known—and the absence on the coast, of a genuine dry season, though a relatively dry period occurs there from December to February. The west winds that prevail throughout the year bring in great quantities of moisture from the Atlantic and the high cold Cameroon Mountains comb this out. Further inland on the West African plateaus the climate has more marked wet and dry seasons, with greater ranges in temperature, and is more agreeable to Europeans.

The natives of the northern interior belong to the Fula, Hausa, and allied stock which have pushed the older Bantu conquerors somewhat coastward so that the latter now are generally south of latitude 7° N. All these races had had more or less intercourse with the English and Portuguese traders before the Germans came in, so that the Bantu, Kru and others along the coast and in the chief mercantile settlements developed and still use a kind of pidgin English which still persists in spite of honest efforts by the German schools to implant among them a pure European language for commerce.

The Hausa and Fula intruders are naturally the more warlike tribes, but they have introduced horses and cattle of which they raised large numbers on the grassy inland plateaus to the north. They build round houses with conical thatched roofs and often group these houses into considerable towns which for protection they surround by strong walls and thorn thickets. Although preferably warlike and nomadic, yet these northerners are industrious and skilful agriculturists when the conformation of their province favors the raising of crops in the rich bottom lands among their hills. They were finally pacified by the Germans and are now very desirable members of the Cameroon peoples.

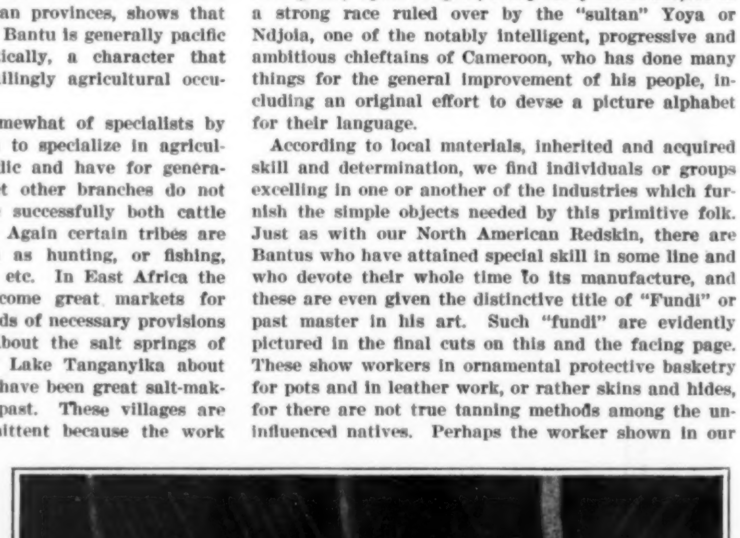
The Bantu tribes retain most of the characteristics they display to the east in German East Africa. They build square houses, usually are active traders, competent, intelligent, desirous to learn new and better methods, and are ruled by a number of independent chiefs. The experience of sensible German officers and explorers in these lost African provinces, shows that the natural disposition of the Bantu is generally pacific when approached sympathetically, a character that harmonizes with their prevailingly agricultural occupations.

The Bantu seem to be somewhat of specialists by nature. Certain tribes seem to specialize in agriculture, others are more nomadic and have for generations been cattle raisers, yet other branches do not specialize or rather combine successfully both cattle raising and tilling the soil. Again certain tribes are famous for such specialties as hunting, or fishing, sisal gathering, salt making, etc. In East Africa the salt-making villages are become great markets for trading salt against other kinds of necessary provisions raised in other districts. About the salt springs of Uvinsa—the district east of Lake Tanganyika about the Malagarasi River—there have been great salt-making centers for generations past. These villages are temporary, or rather intermittent because the work must be done after the seasonal floods recede and leave the salt springs clear. This salt-boiling is a great and wholly indigenous industry whose complicated processes are carried out with considerable organization and skill on a great scale, for it employs regularly thousands of individuals. While it is confined to German East Africa by the nature of things, it is never-the-less a Bantu industry and here exemplifies the ability of the Bantu to organize and carry on a great industry under no other compulsion than that of native needs for the product.

Our photographs come from the town of Fumban (about 5°50′ N., 11° E.), chief place in the province of Bamum, distant ten days' travelling northward from Duala, and prospective terminus of the Manenguba railway from Bonberi to Bare. It is located in a beautiful grassy upland region, occupied by about 100,000 of a strong race ruled over by the "sultan" Yoya or Ndjoia, one of the notably intelligent, progressive and ambitious chieftains of Cameroon, who has done many things for the general improvement of his people, including an original effort to devse a picture alphabet for their language.

According to local materials, inherited and acquired skill and determination, we find individuals or groups excelling in one or another of the industries which furnish the simple objects needed by this primitive folk. Just as with our North American Redskin, there are Bantus who have attained special skill in some line and who devote their whole time to its manufacture, and these are even given the distinctive title of "Fundi" or past master in his art. Such "fundi" are evidently pictured in the final cuts on this and the facing page. These show workers in ornamental protective basketry for pots and in leather work, or rather skins and hides, for there are not true tanning methods among the uninfluenced natives. Perhaps the worker shown in our

Native women making pottery at Fumban



A group of "fundi" or masterworkmen.

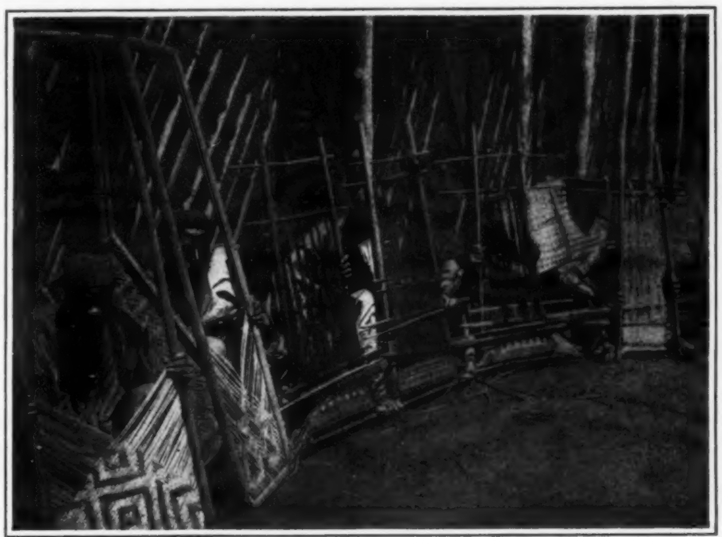
last photograph has come under the influence of Europeans and has secured tanned hides for his workshop.

Naturally a skilful "Fundi," whose work is in great demand will gather apprentices, and perhaps build up a greater workshop. Thus specialization has developed iron workers in spear or arrow points, particularly among the Hausa; makers of iron hatchets, of bows and arrow-shafts, or shields, boat-builders, potters, net-weavers, rope-makers, cloth-weavers, braiders, and others. The potters, strange to say are women, and very skilful ones they are, although they work without a potter's wheel. The flattened lump of prepared clay delivered to them by the pottery-clay diggers, is placed on a sizeable dish-shaped potsherd resting on the ground at the worker's feet. A central depression in the clay lump is made with the fist, and from this starting point the lump is rapidly and skilfully worked by hand into the surprisingly symmetrical forms shown by the lower photographs. The turned lips of the pots are made by pressing a corn-cob against the rim with one hand while rotating the vessel with the other. Sometimes the pots are decorated, then the air-dried vessel is carefully marked with fine-lined simple geometrical patterns by means of the native graphite. After applying the graphite the vessels are then fireburned. Simple fireburning seems to suffice to make the pottery water-tight for the natives are not known to employ any kind of glaze. Pottery is a great industry among the East and the West African natives for every house has 6 to 12 various sized containers of the types shown, while the communities that brew the native beer use a large number of very much more capacious vessels. When the pottery is to be protected or decorated with basket-work covering the latter work is usually done by the hands of skilled male "fundi." The fifth of our views shows a group of these workmen with their work in various stages of completion. It is to be remarked that the designs they braid are also of very simple type; in fact these geometrical designs, though by no means unpleasing, characterize all the decorated work these people produce by weaving, braiding and drawing.

Weaving and braiding, particularly the braiding, have risen to a specially high standard among the Bantu and some very beautiful work is produced. The braiding work is done chiefly by women workers, the weaving rather by the men and older boys. Numerous varieties of mats, plates, marketing carriers, baskets and drinking vessels are skilfully braided with the characteristic geometrical ornamentation worked into them. The great flat wooden food platters are braided with great accuracy, using quite thin long wood shavings or splints of the width of one's little finger. Small vessels of this particular ware, which is water-tight without any special treatment, serve as drinking cups.

Cloth woven from the bark fibre and from the native cotton is still sometimes found far inland in Cameroon, but the cotton print cloths imported from Europe (chiefly Germany, heretofore), are displacing the native product in the favor of the native women, the chief customers. At present the natives are more devoted to weaving the narrow native cotton cloth which our photographs show them making on their native looms. The demand for this product is evidently great and these views of the Fumban factories testify to the ability of the natives to organize and direct plants of considerable size. Evidently the native factory superintendent has to deal with many features common to supposedly superior similar institutions of highly civilized countries. The reader will note that a uniformed overseer walks up and down behind the long line of weaving men and youths, evidently to control the work, and on occasion to stir up a tired, sleepy boy. No such person is shown in the view of the basket factory but perhaps the older women there at work have their eyes on someone not shown in our restricted view.

The native cord and rope used for heavy duty and in nearly every instance where a European might use iron bolts or nails, is made from coconut husk fibre. Our frontispiece shows best how the native uses cord to fasten his loom frames and the like. Smaller lines such as those used to lace their bedsteads, forming the cross support for the finely braided mattresses, are made from the bast fiber of the monkey-bread tree. The very fine elegant lines are made from the raw bast of the leaf of the wild sisal agave. All this weaving and spinning material is collected by tribes whose specialty it is to supply it to the weavers. The same specialization is seen in other lines of native industry.



Fumban natives weaving mats from splints (left hand) and from grass or fibre (center and right hand).

Wood carving is not illustrated here, and seems to be neglected by the East African natives, but the coast tribes in Cameroon are very clever wood carvers. They apply fine carved ornaments to the figure heads for their canoes, and decorate more or less profusely the native wooden seats or stools. The decorations of the wood carvers are not always restricted to simple geometrical designs.

Such designs predominate on the simpler objects, but the finer ornaments on the canoe-stems reveal considerable appreciation of the gracefully curved line and scroll.

From the foregoing it sems clear that co-operative specialized work characteristic of large-scale production plants is quite natural to the Bantu tribes when carried out under familiar conditions of life. If the white man will consult the habits, beliefs and tastes of the tribes he comes in contact with he can certainly develop the native industries and instincts in ways that would prove of mutual advantage. As one traveller, long resident among them remarks, the native industries "testify to the intelligence, industry, and learning capacity of the natives. When they see advantages from their own point of view, natives can perform continuous relatively severe and well organized labor."

Artisan of Cameroon (German), West Africa, painting and embroidering a leather saddlecloth.

Philosophy and Spiritualism

The recent tendencies of philosophical speculation have been strongly in the direction of spiritualistic, as opposed to scientific, explanations. Philosophy is a general name for a wide range of different topics, which have little in common beyond the quality of being very obscure and inaccessible to the ordinary weapons of logic. It thus comprises within its purview some subjects on which so much knowledge has already been accumulated as almost to justify their incorporation into the body of natural science. It comprises some other subjects which are condemned by increasing knowledge and are passing into the sphere of acknowledged superstition. It is upon this less reputable department of philosophy that public attention has lately centered; and we shall be obliged to devote the greater part of this Review to the subject of Spiritualism.

Not that philosophy has been wholly stagnant during the war. Notable advances have been made in Psychology, owing to the great wealth of new material furnished by the study of shell-shock. This peculiar manifestation of hysteria has provided abundant opportunities for hypnotic experimentation, and for testing the theories of Freud and Jung, which had so great a vogue before the war. The doctrines of psycho-analysis and suppressed consciousness have passed with exceptional rapidity through the ordinary stages of a new sphere of thought. A period of incubation and neglect was succeeded by a hail of applause, a sudden leap of the new ideas into fashion. This was followed by intensive criticism, which, fastening upon the most vulnerable features of the theory, seemed at first to discredit the whole. And finally there has supervened a calmer atmosphere, which, while totally rejecting much of the new psychology, accepts a large part as constituting real and important progress. It has now come to be generally held that Freud enormously over-estimated the influence of sexuality in determining hysterical manifestations. When once we cut out this preoccupation with sex, we find much of the highest value in his doctrines, which confirm and supplement the writings of Janet.

It is, however, not in these higher grades of philosophy that the public have been interested. Philosophy at all times has been the arena of a never-ending battle between emotion and intellect. Man is born with powerful desires and cravings; when his mind is undisciplined, he accepts his desires as the criterion of truth. He ardently wishes a certain theory to be true, and he forthwith affirms that it *is* true. You produce facts which show that it cannot be true, and he refutes you by calling you a materialist, and by refusing to admit the facts into his mind. The infinite tragedy of the war—a tragedy so great that a human mind can no more conceive the miseries of it than it can conceive the distance of a fixed star—has brought in its train a powerful set of desires, perfectly natural, perfectly intelligible, but strongly reinforcing the emotional obstacles to the perception of truth. Now truth is the single purpose of science; and men of science must not allow the common people to believe that things are true merely because they happen to be ardently desired. Yet this, up to date, is the sole basis of spiritualism, which has recently acquired such immense vogue.

Of the many works lately published on this subject, only one, *Spiritualism and Sir Oliver Lodge*, by Charles A. Mercier (The Mental Culture Enterprise) has any claim to be considered scientific. It is indeed one of the most brilliant expositions of the subject that has yet been published. Dr. Mercier adopts a purely logical attitude in his criticism, which is mainly directed against Sir Oliver Lodge's *The Survival of Man.* Of special importance, coming from Dr. Mercier, is his experience that the pursuit of the occult, and especially of telepathy and so on, "leads to a morbid frame of mind, and tends to render those who are at all predisposed to insanity an easy prey to the disease." In this experience he is not alone, for he quotes in support the view of Dr. G. M. Robertson, Superintendent of the Royal Asylum of Morningside, Edinburgh. Spiritualism appears to have special fascination for the weaker members of a community.—*Science Progress.*

Physical Relativity*

A Survey of Old and New Hypotheses in this Field

By G. W. de Tunzelman

The Relativity Hypothesis, also known as the Relativity Principle, which has recently been developed into a far-reaching theory, has been a subject of controversy and ever-increasing interest among physicists for about a quarter of a century. It originated in the failure of the celebrated Michelson-Morley experiment, made in the year 1887, to obtain evidence of the motion of the earth through the ether of space.

The general principles of the universally accepted Faraday-Maxwell representation of the transmission of electromagnetic action by means of a medium, as opposed to the theory of action at a distance, showed that any visible optical effects due to the relative motion of ether and matter must, if existing at all, be exceedingly small. For no effect proportional to v/c, the ratio of the velocity of translation of the matter relatively to the ether, to the velocity of light in free ether, about 300,000 kilometers a second, was to be expected, but only effects proportional to the square and to higher powers of this ratio.

It was suggested by Maxwell that it might be possible to detect a difference in the time of propagation of a ray of light between two points at a fixed distance from each other, when the straight line joining them was placed, first in the direction of the earth's orbital motion, and then in a direction at right angles to it. The highest value that could be attained by v would be that due to the motion of the earth through an ether at rest, and the principal component of this, amounting to about 330 kilometers a second, will be that due to the orbital motion. The component due to the earth's rotation is not quite half a kilometre a second, and may be neglected in comparison with the former. There will also probably be a component of unknown amount due to the motion of the whole solar system through space. But this will increase or diminish the component due to the orbital motion according to the position of the earth in its orbit, so that for at least half the year v will have a value of at least that due to the orbital motion.

The experiment was first made by Michelson in 1881, no effect being observed. It showed that, as predicted by theory, there was no first order effect, *i. e.* no effect proportional to v/c, but the method was not considered sufficiently sensitive to prove beyond doubt the absence of any second order effect, *i. e.* one proportional to the square of v/c. The experiment was therefore repeated with much greater refinements of detail by Michelson and Morley in 1887. The essentials of the apparatus employed consisted of a metallic framework with two arms, OA and OB, at right angles, and as nearly as possible of equal length, provided at their free ends with metallic mirrors perpendicular to them, and with a mirror of unsilvered glass at O, with its plane bisecting the angle between them. A convenient source of light was placed on AO produced through O, and a telescope was fixed with its axis in the line BO produced through O. The whole arrangement was bolted to a stone block floating in mercury, so that the arms lay in a horizontal plane, and could be rotated slowly and steadily about a vertical axis. A beam of light from the source would then be split up at O, part being transmitted to A, reflected back to O, and part of this reflected along the axis of the telescope. The smaller difference in the lengths OA and OB would give rise to colored interference fringes. The apparatus was adjusted so that the fringes were as sharply defined as possible when OA represented the direction of the earth's orbital motion. The ray would then travel from O to A with the velocity $c + v$, and from A to O with the velocity $c - v$, while the other part would travel from O to B and back again with the velocity v. Simple geometry will then show that the time taken by the former will be greater than that taken by the latter by one part in a hundred millions, the ratio v^2/c^2. If the apparatus were then turned through a right angle, making OA instead of OB perpendicular to the component of orbital motion, calculation shows that for a velocity of 30 kilometres a second the fringes should be displaced by an amount equal to about two-fifths of the distance between two successive fringes, provided the arms OA and OB were 11 metres in length. The actual arms were much shorter, but their effective length was increased to 11 metres by an arrangement of additional mirrors reflecting the rays backwards and forwards. The apparatus would have indicated a displacement of about a twentieth of the amount expected, but the result was entirely negative. The expected retardation in time was rather less than the thousand-million-millionth of a second.

If, however, there were no drift through the ether, it would follow that the earth carried a layer of ether along with it, and if this were the case, so also would the other planets. But this would necessarily give rise to eddies in the ether, and other optical results showed that its motion must be entirely free from eddies, or, in other words, free from any trace of spin.

It was suggested, almost simultaneously, by Fitzgerald and by Lorentz, that the null result would be accounted for if the whole apparatus, in common with all solid bodies moving through the ether, underwent an extremely minute contraction in the direction of motion, of an amount which, for speeds comparable to that of the earth's orbital motion, would be proportional to the square of the speed, and for this speed would amount to about one part in two hundred millions, or about 6½ centimetres in the earth's diameter. This seemed a startling proposition, but reason was shown for anticipating some contraction, and a little later, some new observations led Lorentz and Larmor by two very different paths, neither of which had any apparent relation to the Michelson-Morley experiment, to the conclusion that such contraction must occur, and that its amount would be exactly that required to explain the null effect. But other attempts, made in very diverse ways, to obtain evidence of the motion of material bodies through the ether were all defeated by some corresponding compensation, just as though the forces of nature were in a conspiracy to prevent our attainment of the evidence sought for.

It was therefore suggested by some physicists that, under the title of *the principle of relativity*, it should be assumed as an axiom that it is inherently impossible to obtan experimental evidence of the motion of material bodies relatively to the ether. In order to form a starting-point for physical argument, this hypothesis was embodied in a statement to the effect that to any observer, whatever his own motion might be, light will appear to travel through space, that is to say, through ether free from matter, always in straight lines and always at one and the same speed. Some out-and-out relativists even proposed to discard the ether, as a mere framework existing only in our own minds, mainly on the ground that it would simplify the fundamental differential equations of electrodynamics. But this simplification would be obtained at the expense of reducing their content, in that it would leave out of account the existence of so firmly established a phenomenon as the inertia of free-travelling radiation, exhibited in the pressure exerted by a ray of light upon any material body upon which it impinges. And the existence of such a pressure is a direct consequence of the universally accepted Faraday-Maxwell theory, which led to its being sought for and experimentally verified by Lebedeff. Moreover, the discarding of the ether, by making anything in the shape of a mechanical interpretation of electrical action impossible, would render the interpretation of these simplified differential equations in terms of definite physical concepts almost, if not altogether, impossible, and differential equations, although most valuble guides in the interpretation of nature, can hardly be regarded as in themselves constituting such interpretation. The elimination of the ether from our representations of physical phenomena would have the further effect of reopening the age-long controversy between Newton's relativist critics and the supporters of his view that absolute motion in space, and hence also absolute direction in space, are legitimate physical concepts.

According to the older relativity theory, the Copernican system of astronomy which takes the sun as the center of our solar system, consisting of sun, planets, satellites, asteroids, comets belonging permanently to it, and, finally, its meteorites and cosmic dust, is not a more correct representation than the Ptolemaic system, which took the earth as center, but is merely a simpler one, enabling the phenomena to be correlated by a simpler system of mechanics than would be required if the latter were adopted.

Consider further such problems as are presented by the shape assumed by the surface of a liquid in a bucket rotating about a vertical axis through the center; the figure of the earth, approximately an oblate spheroid; the resistance of a spinning body, such as a top, and of the earth itself, to any displacement of its axis of spin except in either of the two opposite directions in which that axis might be prolonged; the resistance of a swinging pendulum to the displacement of its plane of swing. A freely suspended pendulum of considerable length and mass was, indeed, employed by Foucault as a means of demonstrating the actual, or absolute, rotation of the earth, its movements being such that they could be explained most simply, and, on the basis of the accepted principles of mechanics, could be explained only on the assumption that the pendulum tended to conserve the absolute aspect in space of its plane of swing. Sir Isaac Newton regarded phenomena of this kind as definitely indicating absolute rotations, and therefore absolute directions in space, and has expressed that opinion in unequivocal terms. One of the ablest of his recent critics, H. Poincaré, in *La Science et l'Hypothèse*, objects to Newton's position, that he attempts to explain relations between phenomena by means of the notions of absolute direction and absolute rotation, involving the notion of absolute space, which Poincaré, in common with all the thoroughgoing advocates of the older relativity, ancient and modern, maintain to be physically inconceivable to the relatively constituted human mind. I have dealt elsewhere[1] with this question in much greater detail than is possible within the limits of space here available, and I must confine myself to very briefly summarising the conclusions there aimed at, to serve as a basis for understanding the nature of the new relativity theory, which, unlike the older one, is not built upon a philosophical foundation, but must be regarded rather as a legitimate hypothetical point of view which appears at present to offer considerable promise of leading us to the discovery of new physical truths.

Space, for the philosophic relativist, is the geometrical abstraction of pure extension, and in this sense, absolute space is an expression which does not appear capable of representation in the form of a definite mental concept; but we must guard ourselves against drawing the conclusion that there cannot be physical phenomena indicative of absolute motion and direction in space, for this would be to assume that our minds are to be accepted as measurng the possibilities of the physical universe. Newton's writings show clearly that, although he seldom referred explicitly to a medium filling all space, and never discussed its nature, he firmly believed in its necessity, if only for transmitting the action of gravitation. His attitude on the subject is expressed in the remark that: "Although practically, and at present, nothing is to be accomplished with this conception, we might still hope to learn more in the future concerning this hypothetical medium; and from the point of view of science it would be in every respect a more valuable acquisition than the forlorn idea of absolute space." I therefore consider that we are justified in the conclusion that Newton regarded space as occupied by a physical reality, the ether, which formed the requisite framework of reference, although, perhaps, too dimly outlined in his mind to enable him to crystallise the concept into a statement which would have carried conviction to the minds of his contemporaries.

Poincaré argued, in the work previously referred to, that the inhabitants of a planet, so veiled in clouds that no external bodies would be perceptible, could not infer with certainty that the planet was rotating, but only that such an assumption would provide the simplest basis possible for a system of mechanics. But he so far qualified his contention in a later work, *La Valeur de la Science*, as to admit that the assumption would make it possible to establish so much wider a correlation among physical phenomena that it might be considered as of the same order of probability as the reality of the external world. That is to say, he admitted that practical, though not theoretical, certainty of the rotation would be attainable by the inhabitants And theoretical certainty must be regarded as unattainable in any conclusions derived from experience.

Bertrand Russell has shown, in his *Principles of Mathematics*, that strictly demonstrable *mathematical* concepts of absolute time, and of absolute position and direction in space, are attainable, and he upholds Newton's actual verbal expressions from this point of view. But in his references to absolute motion, Newton was not dealing with the purely mathematical concepts of rational dynamics, but with the physical concepts of practical dynamics—quite another matter.

In order to investigate even so simple a case of motion in space as the path of a raindrop relatively to a

*From *Science Progress*.

[1] *Treatise on Electrical theory and the problem of the Universe* (1910). Chapter V.

fixed point O on the earth's surface, we must choose some framework of reference, and as simple a one as any would be to imagine three straight lines of lengths sufficient to extend to the limits of the field of motion, one east and west—the X axis, say, one north and south —the Y axis, and one vertically up and down—the Z axis. Then the position of any point P, relatively to O, can be specified by the lengths of three straight lines, x, y, z, representing the distances from the planes YZ, ZX, XY, *to* P, and therefore parallel, respectively, to OX, OY, OZ, reckoned positive if drawn eastward, northward, or upward, and negative if drawn westward, southward, or downward. Then x, y, z are called the co-ordinates of the moving drop, or, strictly speaking, of the center of the drop, at the time t, reckoned from a moment selected as the starting-point in time. Since we know with great accuracy the motions of the earth relatively to the center of the sun, we could then determine the motion of the raindrop relatively to the sun's center. We should simply imagine a similar set of axes with its origin at the sun's center and parallel to X, Y, Z, respectively at the time $t = 0$, the starting-point in time. We could then determine at any time t the co-ordinates of the point O relatively to the sun's center and the angles between the corresponding axes, and hence the co-ordinates of the point P relative to the sun's center. Similarly, if we knew the earth's motion through the ether we could find the co-ordinates of P relatively to a set of axes fixed in the ether, the terrestrial axes and the etherial ones being coincident at the time $t = 0$. But without knowing the earth's motion through the ether, we can picture it without difficulty. For the ether of present-day physics must be considered as a substance of great density filling all space and allowing material bodies to pass through it very much as a piece of wire gauze can be drawn through mercury, but with the difference that the ether offers *no* resistance to such motion, and that it remains fixed in position like a solid, its smallest portions being capable only of making minute vibrations about their permanent positions, instead of wandering freely from place to place, like the particles of a liquid.

By adopting Riemann's most fruitful suggestion of regarding space as a manifold, we can form, not quite a physical concept, but what may be called a mathematical concept, of absolute position in space, without the aid of the ether. Consider a straight line of length a as traced out by a moving point, giving a one-dimensional point-manifold. Let the line trace out a square by moving through a distance a at right angles to its direction and in one plane, giving a two-dimensional point-manifold. Let the square trace out a cube by moving through a distance a at right angles to its plane, giving a three-dimensional point-manifold. So far all the points may be considered as existing simultaneously, for no point has been required to move into a position already occupied. And this simultaneous existence is characteristic of the conception of space. The division between two successive positions at every stage in the motion is a division between *here* and *there*. But in forming the line as a manifold of points, the plane as a manifold of parallel straight lines, or the cube as a manifold of parallel planes, we may alternatively regard the division as between *before* and *after*, each thus giving a different representation of the one-dimensional time-flux. Now mathematical analysis, which is nothing but a highly developed system of formal logic, shows beyond the possibility of question that the obstacle to the indefinite continuation of the former process is due entirely to the limitation of our power of visualisation of the relations, and not to anything inherent in the relations themselves. It would therefore be quite legitimate to represent what we call the present state of the universe, not as a division between a past which has ceased to exist and a future not yet existing, but as a division between two continuously existing systems. The three-dimensional space p in which our minds picture the external world, by the correlation of the impressions derived from our senses, a process which begins in earliest infancy, would then form, at any given instant, a division between two portions of four-dimensional space. To an intelligence capable of such a visualisation, they might be pictured as existing simultaneously. If two observers at different points on the earth's surface desired to compare the results of the study of a moving point, say an agreed point on the moon's surface, their space framework would differ, for the axes would in general differ in direction, and be drawn from different origins. Therefore calculations would have to be made, and would be made by Euclid's geometry, which we know by experience to be reliable so far as ordinary astronomical observations are concerned. But whether this would be the case for calculations of the minute accuracy requisite in such a case as the Michelson-Morley experiment we cannot be sure. For the Euclidian geometry involves axioms and implicit assumptions founded on ordinary observation, and these may be only approximately true. Such is Euclid's axiom of parallel straight lines, which leads to the conclusion that the sum of the three interior angles of a plane triangle is equal to two right angles, and Lobachefsky has shown that two different and perfectly self-consistent systems of geometry are derivable from the alternative assumptions that the sum of these three angles is, respectively, greater or less than two right angles. If the difference were small enough, either of the resulting spaces would be indistinguishable from Euclidian space, but in neither of them could a straight line be moved from one position to another without change in size or shape, as Euclid tacitly assumes in the fourth proposition of his first book. Indeed, a straight line, as we conceive it, could not exist, and would be more properly described as a straightest line. The time would be the same for the two observers, but this would not be the case for observers on different planets, and the correlation of the two time systems would depend on the speed of transmission of a light signal through the ether, from one to the other—that is to say, on the very question which it is sought to determine.

Minkowski was the first who succeeded in finding a space-time framework which would be the same for every observer, wherever and whenever he might be. He showed that this would be the case for a system of four axes at right angles to one another in a four-dimensional manifold representing space and time together, but without distinguishing between them. He called this space-time, and showed that, while it remained invariable, its resolution into space and time separately gave rise to components which depended on the motion of the observer. It will be obvious from what has gone before that space-time looked at from another point of view would be identical with a four-dimensional space-manifold, so that the geometrical treatment developed for dealing with the latter will be immediately applicable to the former.

The possibility now appears that this demonstrated variability of the space and time framework of ordinary physics may be of such a nature as to nullify, by an exact compensation, any and every evidence which we might otherwise hope to obtain by experience of the contraction of material bodies in consequence of their motion through the ether, just as no conceivable experiment could make a man aware of an increase or decrease, however great, in his own size, if the whole scale of nature simultaneously changed in the same proportion. The assumption, as a working hypothesis, that this possibility may prove to be true, provides a perfectly legitimate basis for a physical theory, and now forms the starting-point of what physicists mean by the expression *theory of relativity*.

The ultimate aim of all physical theory in the present stage of our knowledge is the expression of phenomena in terms of strains set up in the ether and of the stresses which give rise to them. The relativist's aim is, therefore, to show that a more complete correlation of physical phenomena is obtainable in terms of stresses and strains of the ether of the Minkowski time-space than in terms of the older theory. Even, however, should the relativity theory reach a development realising this expectation, we should, so far as we can see at present, have to translate our results into terms of the older theory, or something corresponding to it, before we could form physical conceptions of them—that is to say, before we could even think intelligently about them except in so far as we could satisfy ourselves with mere mathematical concepts. We should, however, expect to be able, by means of the wider theory, to resolve some of the difficulties at present confronting us, and then to revise the existing theory more or less completely, without transcending the concepts of space and time to which our powers of visualisation are restricted.

No physical theory that human intelligence is capable of constructing can ever be more than a very imperfect model of natural phenomena. Should it prove possible, and it appears probable that it may, mathematically to extend our modelling beyond our powers of direct physical conception, we shall have to apply a similar process to such models, modelling them in their turn, in order to bring them within our limits of physical conception.

Newton's mechanical world-models, and those of his immediate successors, were imagined as built up of material particles of size apprehensible to our senses, and any such system possesses the property of a mechanism—that the relations between its constituent parts at any instant are determinable, provided our mathematical methods are sufficiently powerful, from a knowledge of the relations at an instant immediately preceding or succeeding it. That is to say, from a complete determination of the system at any one instant we can deduce its state at any past or future time. Newton's own mathematical methods, great as was their advance on anything previously known, were adequate only to the solution of comparatively simple problems. Lagrange extended them so far as to give a complete solution of any mechanical system which can be completely specified in terms of co-ordinates. And these co-ordinates need not be of the simple character previously referred to, but may be any measurable quantities of any nature, provided their number is sufficient to determine the system, *e. g.* in the case of a system of material particles, three times the number of particles requiring distinct consideration. But in many modern problems relating to molecular and electrical phenomena the number of co-ordinates involved is practically infinite, *e. g.* in the case of the molecules in a gas. If, however, such systems remain, during the period considered, in a steady state, *i. e.* free from changes in constitution, closely approximate solutions may be obtained in terms of a limited number of co-ordinates obtained by a process of averaging. That is to say, the system must be one which can be treated as capable of being brought back to any previous state by purely mechanical means, such as reversing the sensible velocities. The Lagrangian equations can be most easily obtained by Sir William Rowan Hamilton's *principle of least action*, which is applicable to all such systems. The potential energy, W, of such a system can be expressed in terms of the co-ordinates only, and the kinetic energy, T, in terms of the co-ordinates and their first derivatives with respect to the time. The action determining the motion is taken as the difference, $T - W$; and the principle asserts that when the system passes from its state at one instant to its state at any other, the path followed—*i. e.* the sequence of changes through which the system pases—will be such that the average value of this difference, during the interval of time occupied by the passage, will be smaller for the actual path than for any other possible closely adjacent path. The principle is expressed mathematically by the equation—

$$\delta \int_{t_0}^{t_1} (T - W)\, dt = o,$$

where t_0 and t_1 are the initial and final values of the time.

Hilbert succeeded, in 1915, in generalising Hamilton's principle into a form suitable for application to Minkowski's four-dimensional manifold, and in the same year Einstein obtained a set of equations representing the generalised law of gravitation as viewed from Minkowski's standpoint, and succeeded by their aid in arriving at a practically exact solution of a problem which had baffled astronomers for several generations—the considerable discrepancy between the observed motion of the perihelion of the planet Mercury, and the value predicted by Newton's law of gravitation.

These results appear to warrant Lorentz's conclusion that the relativity theory may now be said to have taken a definite form, and I purpose in another article, to which the present one may be regarded as preliminary, to deal with what I think I am justified in calling the general theory of relativity.

Determination of the Compressibility of Solids at High Pressures

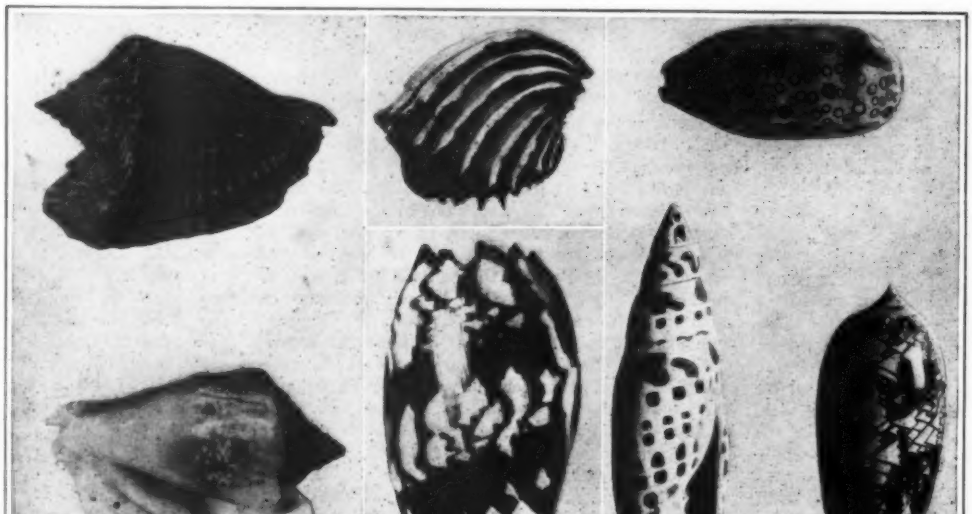
THE compressibility of a number of metals and minerals has been determined for pressures up to 12,000 megabars (1 megabar=0.987 atm.). The principle of the method employed is to compare the change of volume under pressure of a cylinder of the material with that of a similar cylinder of soft steel, the compressibility of which was considered to be 0.60×10^{-6} sq. cm. per megadyne. The solid, surrounded by kerosene, is enclosed in a thick-walled steel bomb fitted with a movable non-leaking piston, and pairs of simultaneous readings are made of the displacement of the piston, that is the volume change and the pressure. The pressure-compressibility graphs for gold, copper, brass, silver, aluminium, and calcite, like that of steel, are linear, but the graphs for zinc, tin, cadmium, lead, a tin-bismuth alloy, quartz, bismuth, and sodium chloride show an appreciable curvature, indicating for those substances a measurable decrease of compressibility with increasing pressure. A comparison was made of the compressibility of two alloys with that of their components. In the case of a simple mixture such as the tin-bismuth alloy, the measurements indicate that the compressibility of mixtures, whose other properties, such as specific volume, electrical conductivity, and specific heat are approximately linear functions of the composition, is related in the same way to the compressibility of the components. On the other hand, the compressibility of alloys of the type of brass is much lower than the sum of the individual compressibilities.
—*Jour. Soc. Chem. Ind.*

The Shell Builders—II

A Brief Introduction to the Study of Conchology

By R. W. Shufeldt, M.D.

[Continued from Scientific American Supplement, Number 2263, Page 310, for May 17, 1919]



Strombus (S. pugilis), Lamellated Clam (Venus lamellata), Diadem melon (Melo diadema), Eyed cowrie (Cypraea argus), Episcopal mitre (Mitra episcopalis), and the Camp olive (Oliva porphyria) [Figs. 21—27]

Occasion was taken in Part I. of this contribution to refer to the Cowries of the family *Cypræidæ*, the genus *Cypræa*, and special reference was made to the Money Cowry—a foreign species with a long and very interesting history. Many years ago I collected specimens of the Measled Cowry (*C. exanthema*) on one of the Keys of the Bahamas. It was a wonderful sight to see these beautiful shells as they, propelled by their inmates, moved deliberately over the dark rock just above the surface of the water. These specimens are still in my collection, and one never tires of seeing and handling them. On the back of a large one, some four inches in length, the color is a very deep chestnut, and this is speckled all over with snow white spots, each half the size of a buckshot. Beneath, the shell is much lighter, and the teeth are of a rich sepia shade. Sixty years ago, Captain Frank Skiddy, of Stamford, Connecticut, then an old gentleman, presented me with a beautiful specimen of the Argus or Eyed Cowry (*C. argus*), which he said had been over a century in the possession of man,—that is, civilized man; how long the natives of the island in the Indian Ocean where it was collected had owned it, there was no telling. It is safe to say, however, that it has been in man's possession for a period extending over two centuries. The back of this remarkable shell is here shown in Fig. 21. Its ground-color is of a buffy brown, with three darker bands crossing it transversely of a deeper shade. This ground-color is speckled all over with beautiful little rings of dark brown of different diameters, which vary in size and are but rarely tangent to each other. Some six or eight are thicker than those in the main grouping, and each of these have a smaller ring inside of its circumference. Below, we note that the "teeth" are of a medium shade of brown, and the entire shell is wonderfully glossy.

The third cut in the lower line of our group shows a fine shell, examples of which are to be found in nearly all collections. It is known as the Episcopal Mitre, and belongs to the genus *Mitra* of the *Mitridæ*. These shells often attain a length of five or six inches, while the habitat is certain islands of the Philippines and Ceylon. Miss Rogers says of this species that it "is fortunately a shell wdely distributed in tropical seas, else it would not be within the reach and means of amateur collectors; as it is, no one needs to go without it. Its tapering spire of smooth, solid whorls is creamy white, overlaid with orange spots, in regular winding rows. The spots just below the sutures are large and irregular. Those further below are orderly, close squares. The large spots are darker than the others. The lip is toothed towards its base."

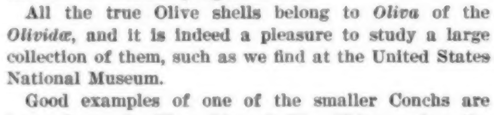
Another Mitre shell—Swainson's Mitre (*M. swainsoni*)—occurs on our Atlantic coasts in deep water off Cape Lookout, and it has also been collected in the West Indies.

On the California coast we meet with a small mitre called the Moor Mitre (*M. maura*). In life it has a black, skin-like covering; but when cleaned and polished it is a beautiful species of a dark brown color, with pale, linear markings running both ways on its surface.

No account of shells would in any way be perfect were we to omit mention of the remarkable Olives. A good example is here given in Fig. 23, it being the elegant Camp or Porphyry Olive (*Oliva porphyria*), which occurs from Panama to Mazatlan. We call it the Camp Olive for the reason that its *white* markings resemble a lot of "A" tents, pitched in irregular rows. This shell is like a highly polished porphyry or fine china, being correspondingly glossy. It is the largest Olive known. Its ground-color is a rich pinkish cream, with markings in vandyke brown, and its inhabiting mollusk is extremely agile in life.

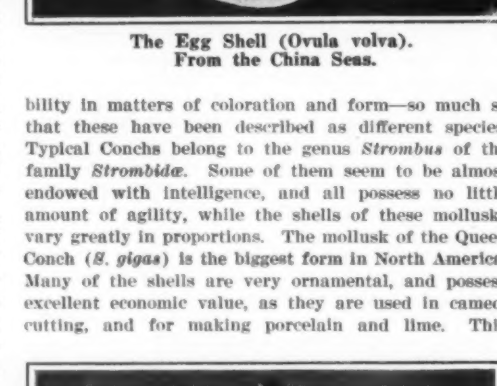
All the true Olive shells belong to *Oliva* of the *Olividæ*, and it is indeed a pleasure to study a large collection of them, such as we find at the United States National Museum.

Good examples of one of the smaller Conchs are here shown in Figs. 24 and 25. This species—the Fighting Conch (*Strombus pugilis*)—was obtained by me in Key West, Florida, it being very abundant on the coasts of that State. It exhibits a wonderful varia-



The Egg Shell (Ovula volva). From the China Seas.

bility in matters of coloration and form—so much so that these have been described as different species. Typical Conchs belong to the genus *Strombus* of the family *Strombidæ*. Some of them seem to be almost endowed with intelligence, and all possess no little amount of agility, while the shells of these mollusks vary greatly in proportions. The mollusk of the Queen Conch (*S. gigas*) is the biggest form in North America. Many of the shells are very ornamental, and possess excellent economic value, as they are used in cameo-cutting, and for making porcelain and lime. This species has an interesting, not to say romantic history.



American Thorny Oyster (Spondylus Americanus). From the West Indies.

Our Fighting Conch, mentioned above, bears transportation very well; and with ordinary care alone, many of them are sent to northern cities, to be studied in salt water tanks and aquaria. They may occasionally be found in the pet and animal stores of Philadelphia; and, while they are voracious feeders in nature, it is said they often decline all food entirely as captives. Years ago, these little Fighting Conchs were very abundant on the south Floridan beaches, where it is interesting to watch them when left high and dry at low water. Should one make the attempt to pick one up, the mollusk immediately gets busy to effect its escape. This it does by plunging its claw-like operculum in the firm, wet sand, and by a series of leaps and overturnings, it attempts to reach the sea. Should any part of its path be down hill, so much the better for its progress; and it is extraordinary to note how the animal manages to get around angles and dodge objects in its way. It is said that they may even leap out of a fishing boat, should circumstances favor the use of its "hook."

Miss Mary Rathbun has described a small crab that lives within the shell of this stromb, much as the oyster-crab lives between the valves of that bivalve. She has named it *Pinnotheres strombi*. Both the columbella and the shell-lining of the Fighting Conch is highly polished, the lip being beautifully colored by blends of orange, purple and pink; the back of the shell is usually of a rich brown.

The West Indies is the great center for the conchs, and they vary notably in form, size and coloration.

That Australia has some curious bivalves will be appreciated by a glance at Fig. 26, where the Lamellated Clam (*Venus lamellata*) is shown on side view. This curious shell is of a pale clay color, the conspicuous lamellations numbering about nine on each valve.

In Part I. something was said about the Melon Shell, seen upon back view at bottom center of our group view, it being the Diadem Melon (*Melo diadema*), so called on account of a circlet of conspicuous processes or spines surrounding its indrawn spire. These carnivorous mollusks, of which there are three species, are confined to the Indian Ocean and Australia, the "Diadem" belonging to the molluscan fauna of the latter.

There are about fifty species of the genus *Ovula* constituting the family *Ovulidæ*, and we call them Egg shells, though the resemblance to an egg is certainly very remote. As a matter of fact, they are allied to the Cowries, in habits as well as in their morphology; their average form is well shown in *O. volva* of the Philippines, Japan and China, here shown in Fig. 28. It is pure white, slightly glossy, and smooth. Specimens are said to be found that are of a "brownish flesh color," barred by indistinct striations. There are several very handsome species in the group, for example the Great Egg Shell (*O. ovum*), which is three or four times the size of the species here shown in Fig. 28.

Over seventy species of Thorny Oysters are known to conchologists, and more than that number of fossil ones have been described. All of these fall in the family *Spondylidæ*, and have been relegated to the genus *Spondylus*. A fine example of a Thorny Oyster is here shown in Fig. 29, it being the American Thorny of Bermuda and the West Indies (*S. americanus*). It may attain a length of at least six inches; and, like many of its congeners, its china-like valves are ornamented; but sometimes we meet with pale red or even yellow ones. As to the valves, they are radiatingly ribbed, quite independently of where the spines are attached.

Rarely are these various species of Thorny Oysters

free, they being attached to one thing or another as in the case of our common oysters. A very remarkable character about them is the hinge to the valves, where the interlocking teeth are so curved and complicated that, when unlocked, it requires no little time, study and patience to lock them again. I have seen an old conchologist take nearly a minute to do this where the hinge was unusually complicated as in some species.

Thorny Oysters inhabit the warm waters of subtropical seas, and ***Spondylus gædaropus*** appeared at the feasts of the early Greeks long before this country was discovered. Indeed, Aristotle gave the name ***Spondylus*** to the genus and Linnaeus retained it. Some of the forms are most richly colored, the reds and oranges predominating.

Thorny Oysters have always been great favorites with shell collectors, and for reasons pointed out above. A writer at hand says the "adjectives before their names will indicate the striking character of some of the species: dyed, variegated, painted, strawberry, orange, yellow, crimson-dyed, amber, dusky, violet, white-spined, many-spined, bearded, cat's tongue, leafy, hedge-hog, porcupine, branched, fingered, crumpled. Some aristocrats are called royal, princely and imperial."

We now come to a group of shells, the *Haliotidæ*, that enjoy a world-wide reputation, a fact not to be wondered at, for they not only occur in many seas but their animals are consumed as food. The pearls, when found in them, have considerable value; and, finally, the shells, when cleaned up and polished, possess marvelous beauty, and are for this reason used in the arts and trades by the thousands. This family *Haliotidæ* contains but the one genus *Haliotis*, to which have been relegated a long list of specific forms, each having an array of characters in common not found in any other type of mollusk or shell. These latter are known by not a few vernacular names that are various as the nations that have invented them. With us they are extensively known as "Ear Shells;" but for what reason it is not easy to say. Surely the outline is not that of the human ear, as the shell lacks a lobe, a tragus, and, indeed, any of the usual aural characteristics. In fact, the outline of an *Haliotis* comes quite near being a broad ellipse, slightly pointed at the marginal termination of the row of foramina that puncture it.

The most euphonius name they bear in English is that of Abalone, and by this they are known from one end of the Pacific coast to the other—particularly on the California coast. All the species are salt-water forms, and they inhabit the rocky shores, at varying depths, of not only California but of certain European waters, as well as those of Australia and some of her off-lying islands. Africa and Japan also have their species, as do various coast-lines of the Indian Ocean. There are no small species among them, and all present pretty much the same shape.

Californians enjoy the soups, chowders and cutlets made from the muscular foot of these creatures, while thousands of them are dried and shipped to the Orient as food; many, too, are eaten in Europe and Japan.

Most of the mother-of-pearl of commerce is furnished by abalone shells of various species, only the larger, however, being collected for that purpose—and the trade is an extensive one. When one comes to examine a typical haliotian shell, its broad, elliptical outline is first noted, the margin above the row of foramina for the tentacular gill filaments being broad and produced inwards, while the opposite one is more or less sharp. Externally is it, in contour, somewhat convex for the inner two-thirds, the broad strip of the remaining third being at right angles to this surface. Where these two surfaces meet, the line of tubercles and foramina run, and run in a curved, linear row. The tubercles are very inconspicuous at first, beginning near the very shallow apex and spire, to become gradually larger and larger to the terminal one at, in, or near the border at the other end. From five to seven of these latter exhibit a subcircular perforation at the apex, which, as already stated, passes the tentacular gill filaments. Most all of the shell is formed of the great, outer coil; for the *Haliotis* is a univalve shell, and this great, outer coil, concave on its ventral aspect, harbors the living animal. There is no operculum. There are two eyes and two lengthy tentacles, the former being supported on stalks of no great length. An abalone also has a tongue with a coarse, file-like surface to it, and this enables the animal to scrape off the rocks various sorts of marine growths upon which it subsists.

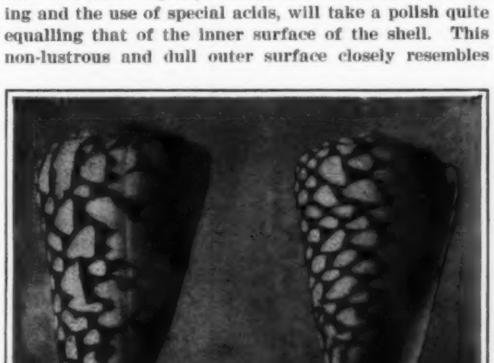
Often the question has been asked as to whether the foramina in the shell indicate the age of the specimen; it is now a well-known fact that they do not. It was settled as soon as competent naturalists had the opportunity to study young abalones, and it was found that in their shells no holes existed, only the row of tubercles. At a certain age, near the middle of the row, they begin to open and allow the gill filaments to come through; as time passes these are sealed up again through the deposit of some substance from within, and others, upon either side, open up. Finally, in old abalones, there comes a time when all are closed, and the individual, in due course, dies. When operative, water passes out through these foramina after flowing over the gills, and the terminal one serves as the anal opening. Careful study, however, has demonstrated the fact that there is no way of getting even the approximate age of any species of *Haliotis* from the stages exhibited on the part of the tentacular openings.

In all the species of *Haliotis* all the inner surface of the shell is heavily covered with *nacre*, which is deposited there by a series of glands in the mantle. This nacre varies in the different species, but in all it is of the most elegant material of the kind imaginable.

Red Abalone (Haliotis rufescens) of California.

Without polish, its pearly surface exhibits all the shades of the rainbow, its lustre and iridescence changing with every turn of the specimen. Many years ago there was an exhibition of abalone shells of various species at the United States Fish Commission in Washington. Many of the specimens were simply gorgeous in the matter of their lustrous linings, and the visitors never tired of examining them. In the center of the concavity of the shell, or near it, one will observe a depression, and upon this is inserted that part of the body that retains the mollusk in its habitation. This is further accomplished through the inturned rim, described above, that extends from a point opposite the apex two-thirds round the concavity.

Externally, the shell of the abalone consists of horny and calcareous layers, which, when removed by grinding and the use of special acids, will take a polish quite equalling that of the inner surface of the shell. This non-lustrous and dull outer surface closely resembles



Marbled Coneshell (Conus marmoratus) from the China Seas.

the rocks over which the mollusk moves, thus greatly assisting in protecting it from its enemies, among which are rats and certain big sea birds.

Upon observing a perfect *Haliotis*—especially one travelling over a rock in clear, shallow water—there are several points to be noted. In the first place, its head projects from under the edge of the shell where the row of foramina terminates. We are enabled to see the above described pair of eyes; the two tentacles, and the broad snout in the center. From this it will be seen that the border having the broad, inturned rim, mentioned above, is the *left side* of the shell. As the animal moves along, it will be noted that the big foot protrudes at the end of the shell where the apex of the spiral is seen.

Encircling the shell we observe the *mantle*, or the margin of it, which is both fringed and of a fleshy nature. When progressing at its maximum rate of speed, the abalone is usually passing over a *smooth* rock with the entire ventral surface of its body in contact with it, the latter fulfilling the function of a locomotory organ. If we attempt to lift a good-sized specimen from the surface over which it is travelling, it will be found that the feat is one quite impossible of accomplishment; its firm hold on the surface is something remarkable. Fabulous tales have gone about, even crept into print, of luckless Chinamen, while collecting abalones on the California coast, having had their hands nipped in between the shell of the mollusk and the rock upon which it was moving, the powerful muscular foot holding the member in such a vise-like grip that to free it was found to be impossible, the man drowning as the incoming tide rose over him. However, there does not seem to be on record any well-authenticated case of this kind. Similar stories are related of the limicoline bird known as the Oyster-catcher, where a gaping oyster has behaved in a like manner when the former made the attempt to secure it with its beak.

The best way to take abalones is from a boat at low tide, as the Chinese do on the California coast; they use a long pole with a metal wedge firmly fastened onto the end. If an abalone be warned in any way of an attack, so powerful is his hold on the rock that it is impossible to tear or punch him off; but if the attack be unexpected and sudden, with the aforesaid pole armed with its metal wedge, it requires but an adroit, well-directed pry to dislodge him, when he is readily secured.

Skilfully cleaned and polished abalone shells—they are also called *aurora* and *rainbow* shells—are the prizes of any one who may possess them. Those collected in this country stand among the finest known, especially the Pacific coast forms, from which a fine grade of mother-of-pearl is obtained. Before the war, tons of these were shipped to Europe, particularly to Paris, where the mother-of-pearl was extensively used in the manufacture of a great many useful and fancy objects, as well as in inlay work on furniture. Fans, buttons, all kinds of knife-handles, card-cases and various sorts of jewelry are made of abalone pearl, and the objects are invariably exceedingly attractive.

It is well know to jewelers that a fine grade of pearls is obtained from the various species of *Haliotis;* they are hidden within the folds of the mantle and not very common. Usually they are of a lovely shade of pale green, and Miss Rogers gives an account of "an ingenious experimenter who trepanned the shell of several large abalones, and inserted small pearl beads next to the mantle. Then he closed the holes with cement. Later he found all the beads coated, and thus transformed into pearls; some were of fine quality. Of course the longer they are allowed to remain the better they become."

Haliotis fulgens, one of our best known and largest abalones, is an elegant species that may grow to become seven to eight inches in length. Spiral undulations, starting at the apex, mark the rough, brown shell on its outer surface. It is crossed by fine radiations, the whole being much obscured by the limy deposit on the shell. In my own collection, a small specimen of this species also has a few barnacles scattered over it. When the outside of the shell is cleaned and polished, the surface is just as handsome as the inner one, which is of extreme brilliancy in the matter of its glow and varied color and iridescence.

A still larger species and *the* pearl shell of the Pacific coast is the Red Abalone (*H. rufescens*) of Swainson, which may grow to become at least nine inches in length. Still another species found there and on the Farrallone Island, is the Black Abalone (*H. cracherodii*), which is black externally and very handsome when polished. Its young have been studied in salt water aquaria, and the adults rarely exceed five inches in length. In the same molluscan fauna occurs the Rough Abalone (*H. corrugata*).

Biggest of all (length ten inches) is the Awabi of Japan, known as the Giant Ear Shell (*H. gigantea*). Its mother-of-pearl is especially fine, and the Japanese consider the animal as a staple article of food. Another Japanese species is the *H. kamschatkana*—a form that links up with our own Californian types.

There is a long list of these shells found in Australian waters—indeed, that is the center for abalones; but ours of the Pacific coast rank them all in the matter of size. One of the best known Australian species is *H. asinina* of Linnæus, a long, and somewhat narrow shell likened to the ear of an ass. It is the only known species possessing such a form, and even it often assumes the form of a kidney.

Europe has its "Ormer" (*H. tuberculata*)—an ear shell with a long and interesting history, extending back to the days of the aborigines of the Continent. It is now callead the "Sea Ear;" while the fishers along the coasts of France, noting the six foramina in the shell, have named it "Silieux."

Cutting Lubricants

Considerations of Theory and Practice that Govern their Use

A MEMORANDUM on cutting lubricants and cooling liquids issued by the British Department of Scientific and Industrial Research was prepared by a committee of the department in connection with a survey of the field for research on lubricants and lubrication. While the bulletin is not claimed to contain new knowledge, it is published in the belief that it furnishes a large amount of useful information which will be new to many users of cutting lubricants and likely to increase the efficiency of production in operations concerned with the cutting of metals.

The *London Times*, in its Engineering Supplement, abstracts the Bulletin as follows:

The materials discussed in the first part of the memorandum, which is by Mr. T. C. Thomson, are classified as soluble oils, which are oily liquids that form emulsions when mixed with water; soluble compounds or cutting compounds, which are greasy pastes that form emulsions when mixed with water; cutting emulsions, formed by mixing soluble oils or soluble compounds with water; and cutting oils, such as lard oil, rape oil, mineral oil, or mixtures of such oils, free from water and soap, which ordinarily do not form emulsions with water.

CHARACTERISTICS AND PREPARATION.

The mineral oils best suited for use as cutting lubricants, either alone or mixed with animal or vegetable oil, are preferably of pale color and low viscosity, ranging from 100 to 200 seconds Redwood at 100 deg. F., those of lower viscosity being used for high-speed conditions and those of higher viscosity for slow speeds. Tinged lard oil, containing as much as 10 or 15 per cent. of free fatty acid, is the animal oil most frequently used, either alone or in admixture; prime lard oil, which is almost free from acid, is more expensive, but is less inclined to gum under severe conditions of heavy cut and high speed. Wherever possible a mixture of lard oil and low cold test mineral oil is to be preferred on account of greater fluidity in the cold. Cottonseed oil oxidizes more readily than rape oil, and should not be used for cutting lubricants that are to be employed in a circulation system. Animal oils are not so easily oxidized in circulation systems as are vegetable oils, and lard oil produces deposits in such systems under severe operative conditions only when the percentage of free acid exceeds, say, 10 per cent. Cutting oils are nearly always used "straight," *i. e.*, without admixture of oils; some of them, containing at least 5 per cent. of free fatty acid and preferably over 20 per cent. of saponifiable (animal or vegetable) oil, may be used either straight or in the form of cutting emulsions. They will emulsify with water to which the requisite amount of alkali (soda ash, borax, &c.) has been added.

Soluble oils are prepared by dissolving a soap (usually less than 20 per cent.) in a mixture of mineral oil (usually less than 70 per cent.) and saponifiable oil (usually more than 15 per cent.). The oils used for making the soap are either animal or vegetable (lard oil or other olein from animal fat, whale oil, wool grease, castor oil, sulphonated castor oil, rape oil, cottonseed oil, resin, &c.), and are saponified with caustic soda or potash. In some cases a small percentage of alcohol or ammonia is employed to promote the formation of the emulsion. Soluble compounds are made on similar lines, except that they contain 10 to 50 per cent. of water and are in a semi-solid and semi-emulsified condition. They are not so easily mixed with water as soluble oils, which therefore are usually preferred.

PURPOSES OF USE.

Cutting lubricants and cooling liquids are used for the purposes of cooling, lubricating, producing smooth finish, washing away chips, and protecting the finished product from rust or corrosion.

The importance of properly cooling the product, particularly under high-speed conditions and with materials such as aluminium which have a high coefficient of expansion, lies in the fact that the material is warmed by the heat developed during machining, and contracts on cooling, its dimensions then differing from the measurements taken during machining. Excessive heating of the tool causes the cutting edge to wear rapidly; in a tool of large section the heat is more rapidly conducted away than in one of small section. Efficient cooling of the tool edge increases output; with high-speed steel the gain in cutting speed on steel and wrought iron is from 30 to 40 per cent. and on cast iron from 16 to 20 per cent. Efficient cooling of the shavings on the side not in contact with the tool is particularly important in tough material, helping to reduce the friction produced by the shavings rubbing against the nose of the tool. Lubrication is of little importance where the manufactured article is made of brittle material, but is very important where the metal is tough and is removed as spiral shavings which grind their way over the face of the tool. The heavier the cut the greater the necessity for lubricating the nose of the tool.

When the requirements of cooling and lubrication are satisfied the finish will be good. Cutting oils of great oiliness are required for a very smooth finish, and for this purpose some engineers find vegetable oils, such as rape or cottonseed, preferable to either mineral or animal oils. Dies, taps, reamers and form tools have a longer life when used on tough steel if a cutting oil is employed in place of an emulsion prepared from a compound or soluble oil. For finish boring, rifling, &c., a mixture of 1 part of castor oil to 3 parts of mineral cleaning oil (gravity about 860-890) has been used with good results; the addition of an equal volume of turpentine substitute (white spirit) causes perfect solution to take place and is said to be advantageous for finish turning on guns and hard material.

The washing away of chips is often quite an important function of the cutting lubricant or cooling liquid, particularly in cases of deep drilling and in most milling operations. In boring deep holes, gun-tubes, &c., a solution of 50 lb. of sodium carbonate and 25 lb. of soft soap in 200 gallons of water has given very satisfactory results. If the cutting emulsion is too weak it will not carry away with it the minute particles of metal and scale, which may prove detrimental to the machine tool.

Good cutting oils used straight will not cause rusting, but those containing fixed (animal or vegetable) oils, such as lard oil with a large percentage of free fatty acid, will give rise to verdigris on brass. Vegetable oils such as rape, with a small percentage of free acid, do not produce verdigris unless they are rancid. Cutting emulsions made up from cutting compounds or soluble oils and water cause rusting if they are used too weak or if they contain acid. Water containing sodium chloride is most destructive to emulsions and must not be used, nor must hard water on account of the precipitate caused by the calcium and magnesium salts in it. Emulsions of oil and water are not stable in the presence of even minute quantities of acid; to a limited extent they can be reformed by neutralizing the acid with ammonia, but excess of alkali may facilitate corrosion.

FACTORS IN SELECTION.

Low speeds and shallow cuts require little cooling and lubrication. Low speeds and heavy cuts demand a lubricant of great oiliness, particularly if the material is tough. High speeds and shallow cuts demand a cutting medium with great cooling properties; hence emulsions are favored and should be used if the speeds are particularly high. Turpentine substitute is a satisfactory lubricant for aluminium, but being inflammable must be used with care. A mixture of paraffin oil and lard or other cutting oil for high speed work on aluminium is also dangerous, and has led to several fires. Cutting emulsions which possess the necessary cooling properties, and are not inflammable, are to be preferred. High speeds and heavy cuts demand a cutting lubricant with great cooling and lubricating properties; hence heavily compounded cutting lubricants of low viscosity must be used. For tough material and heavy cuts an emulsion containing 15 to 20 per cent. of vegetable oil has been reported to be satisfactory.

Cutting emulsions are nearly always used for brittle material, and frequently for tough material if the speeds are high and the cuts light; when the material is tough and the cut heavy it is necessary to employ cutting lubricants used straight and containing 10 to 50 per cent. of animal or vegetable oils, or consisting entirely of such oils. Emulsions, in some cases, have been found to form a deposit on the working parts of automatic screw-cutting machines; this may be avoided by using straight oils, but emulsions should be adopted wherever possible, in view of the present scarcity of oil. The amount of soluble oil or soluble compound used in preparing the cutting emulsion varies from 2½ to 20 per cent.; the richer mixtures are used for severe conditions, and the weaker for light duty or for materials like brass and aluminium, where there is no danger of rusting.

The cutting lubricant may be applied by hand by a drop-feed system, or by some system employing gravity or pumping. In large machine shops the cutting oil is sometimes circulated in pipes throughout the works, returning through other pipes to a central tank; group systems with central tanks are excellent where one mixture is used for all the machines on the circuit. The return pipes should be large and arranged for easy access for cleaning; isolating valves should be employed to sectionalize the system when large; efficient strainers should be fitted on all return pipes and pump sections, and should be cleaned daily. Tanks as a rule, should be cleaned out every four weeks, and return pipes every four months. Any scum formed should be skimmed off the tanks daily. It must be remembered that the oil or emulsion, in any system in which it is circulated over and over again, is exposed to the admixture of dust and dirt from the machine shop and to the oxidizing influence of air. The suction of any pumps that are employed should always be covered to prevent air from being drawn in, since aeration of the oil or emulsion has a strong oxidizing effect upon it.

EFFECTS ON HEALTH.

In the concluding part of the memorandum, Dr. J. C. Bridge deals with skin diseases produced by lubricants. He describes oil rashes as being, generally speaking, of two kinds—one due to the plugging of the small glands at the root of the hairs on the arms and legs of workers, and the other to mechanical injury to the skin producel by metallic particles suspended in the cutting lubricant. Primarily the first is purely mechanical. The plugging of the minute openings of the glands by the mixture of oil and dirt sets up inflammation round the hairs, and this may lead to suppuration or abscess formation. Injury from suspended particles occurs chiefly on the hands, where two surfaces are rubbed together, *e. g.*, the skin between the fingers. Injury to the skin may also be produced by wiping the hands or arms with a cloth or rag when they are coated with a film of fluid in which metallic particles are suspended. Such injury permits the entry of germs and causes septic infection.

In the handling of the constituents of the lubricant before blending care must be taken that they have not undergone changes such as the formation of free fatty acid. Constant removal of metal particles is necessary; filtration, such as is provided on the machines, and centrifugal action are insufficient. When straight oils are used their viscosity can be diminished by heat sufficiently to allow the particles to sink without affecting the lubricating value, and this operation completely removes the particles. Where this procedure is impossible constant change and renewal of the lubricants are necessary. Frequent cleaning of the machines, with removal of all old lubricant from their parts is essential.

Various antiseptics, carbolic acid (1 to 2 per cent.) being the most common, have been added to the lubricant to prevent rashes, and in the case of cutting emulsions disinfectants soluble in water have been used to the extent of 0.5 per cent. for the same purpose. The results, however, have not been altogether satisfactory, and the method cannot be relied on to prevent skin rashes. Heating the cutting oil to 3300 deg. F. for a short period, with the object both of sterilizing it and of increasing its antiseptic or germicidal action, has been suggested, laboratory experiments in America havng shown that oil which has been heated by use possesses rather marked germicidal effects. Apparently heating new oil does bestow germicidal powers on it; the actual temperature required has not been determined but is above 125 deg. C.

Workers whose hands have become the seat of septic infection should not be allowed to work on machines, as they are liable to infect the oil with germs and so infect others. As a general rule frequent washing with soap and hot water is sufficient to bring about rapid cure of folliculitis produced by clogging of the glands. Subsequently the skin may be dusted with zinc oxide and starch powder, and where this has been insufficient a mild antiseptic applied on lint has relieved the irritation and given good results. Septic infection of the skin due to cuts should be treated on general principles with suitable antiseptic dressings.

Covering Power and Illuminating Power of Lenses: Tests and Performance

By C. Welborne Piper

A recent article on the covering power of lenses, raises some points with regard to lenses that are certainly not generally understood, though their practical importance is very great, and some of these points are well worth more detailed consideration. The first to demand special attention is the distinction between covering power and illuminating power. The best way to realize this is to take an ordinary quarter-plate R.R. lens and fix it up temporarily on the front of a large camera, 12 by 10, if available. First of all, open the lens out to its biggest stop aperture, and secure approximately sharp focus on the screen on any object at a reasonable distance, say 20 ft. away. Now remove the focussing screen and look obliquely through the lens. At a certain angle it will be seen that no light is transmitted at all, the two sides of the visible aperture apparently closing together and cutting out all light. Obviously this angle must mark the limits of the largest possible circle of light that the lens can project upon the plate. Next look through the centre of the lens. A perfect disc of light is then seen, but as we move the head sideways this contracts to an ellipse. At a certain angle this perfect ellipse changes to an imperfect one, with pointed instead of rounded ends; in fact, to the shape of the aperture formed by sliding two elliptical openings over one another, but not allowing them to coincide. This change in form is due to the lens mount interfering with the light. Up to this point we simply had an oblique view of a circle, which is an ellipse. We now have an oblique view of parts of two circles which apparently intersect, one being the circular stop aperture and the other the circular lens mount. The angle at which this change takes place is obviously the one limiting the illuminated disc which can be produced by light passing the full unobstructed stop-aperture of the lens, and this circle it is convenient to call the circle of full illumination, while the other may be called the extreme circle of illumination.

Suppose, now, we reduce the stop of the lens. It will be found, on trial, that the circle of full illumination has enlarged, though the extreme circle has not changed. If, however, we change the R.R. for a lens of unsymmetrical construction, the extreme circle will also change; it will become smaller as the circle of full illumination becomes larger if we use the type of lens called the single landscape. What happens to the extreme circle is, however, of small moment, for in any case the illumination near its boundary is so faint as to be photographically of no value. In fact, it is almost impossible to record its limits.

As the ellipse shown by a circle viewed obliquely is necessarily of smaller area than the circle itself, it follows that at the margin of the circle of full illumination the light is rather less than it is at the centre. The diminution is not much, and as the ordinary plate has considerable latitude it is not beyond its capacity to render this really graduated disc as if it were a uniform one. If, however, we go outside the circle of full illumination the visible aperture is very rapidly and materially cut down by the lens mount, and sooner or later we reach an angle where the production of a uniform disc on the plate is impossible. The limits of this angle depend a good deal on the plate and on the exposure, for a plate with great latitude will permit considerable over-exposure in the centre without showing it. Under-exposure on any kind of plate will show a very small uniform disc, but if that plate will permit a considerable increase without spoiling the centre of the image a larger disc of uniformity can be produced. Leaving out the question of plate and exposure makes it difficult, if not impossible, to define the limits of the angle, but seeing that many plates will permit a doubling of what is really a correct exposure, without showing over-exposure, it is convenient to define the circle of uniform illumination as limited by the angle at which the pointed ellipse representing the lens aperture is half the area of the complete circle seen centrally. This angle is termed the angle of semi-illumination, but it should be understood that the definition is a more or less conventional one, probably not far from the truth in most circumstances, but almost certainly well away from it in others.

An actual test giving varied exposures is the only way of arriving at the true maximum limits, and if we start with a very short exposure such a test will be very interesting and instructive, though somewhat expensive. The facts can be illustrated in cheaper fashion by using bromide paper, but the result will afford no criterion of the effects producible on a well-coated negative plate, as the bromide paper has no latitude at all in comparison. It should be observed that with nearly all large-aperture lenses the circle of full illumination is very small; with many not much bigger than half-a-crown. The most rapid and highest class anastigmats will produce much the bigger circles, but in practically all cases we use plates that require still bigger circles to cover them, so the practical limits are always outside that of the circle of full illumination and near that of semi-illumination. This circle also enlarges as the stop is reduced, and not uncommonly we are compelled to stop down to get sufficiently uniform illumination over the plate in use.

It will be noticed that in considering this matter of illumination, as it affects the area of a plate, we are almost obliged to bring in the word "cover," for none other seems to serve. The term "covering power" may be used in this connection, but it is best not so to use it, for in lens catalogues usually this expression does not imply the size of the angle or circle that the lens will cover with uniform illumination, but that which it will cover with good definition, a different matter altogether, and one quite unconnected with the other. Unfortunately, this conventional definition is not always observed, and so confusion has arisen. Some very good lenses have very small covering power compared with their power of illuminating a plate uniformly, and this may be no disadvantage, but it would be a somewhat awkward matter for a dealer to explain to a purchaser whose knowledge of lenses was very limited, and the former could hardly be blamed if in such case he used "covering power" to define the circle of good illumination. An example of such a lens is the Petzval Portrait, which, tested on a plane object, will show very small covering power, but on a suitably curved object will show it to a very considerable extent. The fact is we cannot fairly test all lenses for covering power in the same way. The form of the object surface comes in. An anastigmat or rectilinear may, with more justice, be tested on a plane surface, and the former will have little to recommend it if it does not show a fairly large circle, bigger than any R.R. can produce in the same conditions and much bigger than that which a Petzval may show. But always the type of lens and the purpose for which it is required must be considered. Just as the size of the circles of full and semi-illumination increase as the stop is reduced, so also should the circle of good definition, if the lens is at all a reasonably good one. The most serviceable lens is one that with a moderately small stop will cover the plate with both even illumination and good definition, and one of the most important differences between good anastigmats and R.R.s is that the former will do this with much the larger stop, the result being that as a rule they require only a half or one-third the exposure. This brings me to another one of the points referred to by Mr. Nicol. He mentioned several cases in which R.R.s would serve just as well as anastigmats, and several ways in which photographers could waste money on expensive lenses when cheap ones would have done all they required. The fact seems to be that many photographers do not quite understand what is meant by a high degree of correction in a lens, and place a value on it that their requirements do not justify. First of all, we must premise that no lens is perfectly corrected. If we test two lenses, an R.R. and an anastigmat, at a certain moderately oblique angle, and use a critical test, we shall find astigmatism in both of them. It may be clearly obvious in the first lens and only just perceptible in the other, but it will exist. Clearly the anastigmat is the better corrected, but still not theoretically perfect. Next test both lenses by exposure on a test subject. The chances are that the aberration is not visible in either. The small defect that our microscopic test revealed is masked by the inherent defects of the photographic process. A minute spreading of the light-effect, or lack of sufficient resolving power in the plate, or perhaps lack of minute detail in the subject, has rendered the lens defects quite invisible, and, therefore, negligible. It is then evident that the R.R. is doing the work quite as well as the photographer can desire, while the anastigmat is merely an instrument of greater precision than he needs. At bigger angles he will find marked differences, while always the anastigmat should be the quicker lens, but if he does not use wide angles or short exposures he can do without the anastigmat quite easily.

Yet another point is that the special advantages of the anastigmat are often arrived at by various means of compromises. A little of the critical definition possible in the centre of the field is given up for the sake of getting something more important. It has been said that for fine central definition no lens yet made comes up to the Petzval Portrait, while it is certainly a fact that some good R.R.s will give central definition of a kind that should satisfy the most critical photographer. Somehow or another, when an extremely fine focus is required, even though on only quite a small area in the centre of the field, the tendency seems to be to rush for an anastigmat, when all the time a much cheaper lens would do the work just as well and very possibly even better.

The Position of the Illuminant in Enlarging and Projection

It used to be stated in text-books, or, at least, implied by the diagrams given, that the correct position for the illuminant is such that the condenser brings light-rays to a focus at the first node of the objective. This idea has been proved erroneous, and, in fact, practically impossible with the ordinary uncorrected plano-convex compound condenser. The modern teaching is that the illuminant should be so placed that a small image of the light-source is formed a short distance ahead of the objective; while, if the latter is removed, a similar, but less defined, image is formed near or at the screen.

The rationale of the second method of adjusting the light, however, is seldom properly understood. Many have an impression that the condenser and objective form, in some way, a single corrected optical system, giving uniform illumination. This is correct as far as it goes, but it is not the real explanation, and does not meet all cases, for the reasons to be given.

Whatever may have been the case with early lantern slides, made for use with poor illuminants, the modern slide is not very transparent, neither, for that matter, is the average negative, still less an up-to-date cinematograph film. True, there may be a tiny patch or two of clear glass or bare celluloid, but these merely occupy an insignificant portion of the picture. What follows, then. If the negative, slide, or film is at best only semi-transparent or almost translucent, it must be regarded as to some extent constituting (in conjunction with the condenser) a diffusing medium, graduated so as to compose the various tones of the picture. Now, if the negative, slide, or film, with the condenser, is practically a graduated diffusing medium, it is evident that the chief object to be attained is to illuminate this from behind as evenly and as brilliantly as possible. Other things being equal, this end is secured by bringing the illuminant nearer, since, besides the increased light naturally due to greater proximity, a wider cone of rays then enters the condenser. The adjustment is much simplified in the case of the enlarger and the optical lantern by the fact that the negative or slide is close to the condenser, and therefore receives the beam of light before any portion can come to a focus.

In the case of the cinematograph, where the film is a little distance away from the condenser, instead of being close to it, the factors are different, since the position of the illuminant is partly dependent on that distance, the beam of light having to be concentrated in a small disc on the "gate," in which is the film-aperture or "mask." With that exception the same argument applies.

Both the old and the new method are easily experimented with. For the first, the position of the illuminant may be approximately found as follows. Focus the negative or slide sharply on the easel or screen. From the ratio of enlargement calculate the minor conjugate, and measure an equal distance from the slide or negative, marking it on the bench. This, of course, is the first node. Remove the slide or negative and also the objective, and move the illuminant till the best possible image of the light-source is focussed on a white card supported level with the mark. Then replace the objective and re-insert the slide or negative. In practice this arrangement will be found to give a very fair illumination, quite decently uniform, not because the old theory is anywise right, but from the fact as before explained, that a slide or negative of average density acts, in conjunction with the condenser, as a diffuser, and is in effect an illuminated object, like a stained-glass window or a lit-up clock face. This method has, at any rate, the merit that the light is further from the condenser, and a cracked condenser less probable, though the maximum illumination is obviously not obtained.

Now, having tried the first way, without altering any of the other adjustments, gradually approach the illuminant to the condenser, watching the easel or screen. The increased light on the latter will at once be noted. When the most even result is obtained, remove the negative or slide and hold the white card a few inches in front of the objective. A small image of the light-source will be focussed on it at a certain distance, showing that the second ideal adjustment has been reached. It will be found, however, that this distance may be varied somewhat by moving the light nearer to or further away from the condenser, without particu-

larly affecting the evenness of the lighting, provided the slide or negative is sufficiently dense, which goes to prove the soundness of the conclusions here suggested. —A. LOCKETT, in *Brit. Jour. Photog.*

The Influence of Astronomy on Human Thought

(*Continued from page 343*)

universe. But this unity was first actually proved by the marvelous revelations of spectrum analysis.

The work of Fraunhofer, cut short by his early death, was carried forward by Kirchoff, with the result that in 1859 the spectroscope became the adjunct of the telescope. In 1823 Comte had declared that one thing at least man could never know,—the chemical composition of the celestial bodies. In less than forty years the seemingly impossible had been accomplished. As a result the chemical unity of the universe was found to be a truth of nature. The cosmos was seen to be in very truth a cosmos, connected and inter-related in all its parts.

The history of astronomical science in the last half century has been the record of the triumph of telescope, spectroscope, and camera; as a result of the ceaseless labor of astronomers, several facts are tolerably certain today.

What is the form and extent of the universe? The problem is a very old one, and our conception today is not so definite as that of Herschel when he formulated his famous disc-theory of the stellar heavens.

In the first place, that collection of stars known variously as the Stellar Universe, the Sidereal System, and the Galaxy, although of vast dimensions, seems to be limited in extent. That the universe of stars is finite in extent may be proved by a calculation originally mentioned by the German astronomer Olbers, which was used with great force by Newcomb and Gore in their investigation of the extent of the stellar system. There are three times as many stars of any given magnitude as of the magnitude immediately brighter. Thus, the increase of number more than compensates for the decrease of brightness, and were the stars infinite in number, the whole heavens would shine with greater brilliance than the sun. It has also been shown conclusively that in certain portions of the sky observers have penetrated to the limits of the universe. In these parts large telescopes do not show more stars than smaller instruments, proving conclusively that, in these regions at all events, the universe is finite. It is true that the universe is very vast in extent. The photographs of Professor Max Wolf and Professor Barnard have revealed untold numbers of stars; nevertheless, the starry system seems to be strictly limited.

What of the extent of our universe? Various estimates have been made, and they differ considerably. These distances are generally measured, not in miles but in "light-years"—the number of years which light, travelling at the rate of 186,000 miles a second, requires to travel from the stars to the earth. Seeliger of Munich has calculated that the limits of the universe are about 9,000 light-years from the solar system—which is, roughly speaking, in the central region of the universe. Newcomb reached a smaller estimate —3,000 light-years. More recently, in 1911, after an elaborate investigation, See reached the conclusion that "the most remote stars are separated from us by a distance of at least 1,000,000 light-years." There is, therefore little or no unanimity as to the actual extent of the sidereal system. It is very vast, though finite, and probably only one of a number of similar systems.

Have we any positive knowledge of such systems? Towards the close of the eighteenth century, the view that star-clusters and nebulæ were "island universes," analogous to our Milky Way, enjoyed considerable popularity. In the nineteenth century, it fell into disfavor, and was very generally abandoned after the spectroscopic discovery of the gaseous nature of many nebulæ. As a sweeping generalization, its abandonment was a necessity, for the irregular nebulæ are not star-clusters, but masses of gas, and the star-clusters proper show a tendency to cluster on the Milky Way.

But all nebulæ so-called do not show gaseous spectra. A numerous class—the famous spiral nebulæ—have spectra which, despite individual peculiarities, may be described as continuous. The view is gradually gaining ground that these so-called spiral nebulæ are external universes, analagous to our Milky Way. Professor Eddington of Cambridge, who has made the problem of the construction of the universe peculiarly his own, inclines towards the view. Spiral nebulæ are difficult to account for on any other hypothesis. Not only are they differentiated from other nebulæ by their continuous spectra; they do not obey the law of galactic concentration, and betray no affinities with early-type stars. "The island universe theory," says Eddington, "is much to be preferred as a working hypothesis; and its consequences are so helpful as to suggest a distinct probability of its truth."

(1) On the whole, the theory agrees with the theory of the universe, now widely held, that our stellar system is a spiral nebula. "The two arms of the spiral," says Eddington, "have an interesting meaning for us in connection with stellar movements." The universe appears, according to present-day astronomers, to consist of two great star-streams moving in different directions. On the spiral nebula theory the prevalence of motions in opposite straight lines is explained.

(2) As already mentioned, the spiral nebulæ shun the zone of the Milky Way altogether. According to the island universe theory, this is explained. In that region the external universes are blotted out from view, not only by the star-clouds of the galaxy, but by vast tracts of absorbing matter.

At present, we can only say that the balance of evidence is in favor of the view that, not only is our stellar system limited, but that we can see beyond its confines to other similar systems at distances so vast that the mind is unable to comprehend them, so vast that light will require tens and hundreds of thousands, if not millions, of years on the journey. And we must remember that this collection of island universes, including our own, will in all likelihood form another and greater system of a higher order. Truly, as Richter says, "the spirit of man acheth with this infinity."

Thus, the astronomical view of the entire universe teaches us that it is a unity—one great system bound together by the law of gravitation—in continuous progressive development. The difference between the world-concept of today and that of the Middle Ages may be best realized by a comparison of the view of our earth's position then held with the view current today. The medieval cosmology placed the earth in the center of the universe; it was not only relatively but absolutely the most important part of creation. Sun, moon, and stars were created 6,000 years ago on the fourth day of Creation, for the sole purpose of giving light to the earth's inhabitants. Today, our view of our world's place is vastly different. So far from being the center of the universe, the earth is merely one of the planets revolving round the sun, and by no means the largest. The sun itself— relatively vast though it is— is by no means the chief body of the cosmos; it is merely a rather subordinate star—one of five hundred million or more, merely one shining speck in the jewelled casket of heaven. Flammarion, in two short passages, brings out very clearly and impressively the utterly insignificant place which our world actually occupies in the scheme of things. Speaking of the celestial motions, he says,—"Such are the stupendous motions which carry every sun, every system, every world, all life, and all destiny in all directions of the infinite immensity, through the boundless, bottomless abyss; in a void forever open, ever yawning, ever black and ever unfathomable; during an eternity, without days, without years, without centuries or measures. Such is the aspect, grand, splendid, and sublime of the universe, which flies through space before the dazzled and stupefied gaze of the terrestrial astronomer, born today to die tomorrow, on a globule lost in the infinite night.

"Our science is but a shadow on the face of the reality. Infinity encompasses us, on all sides life asserts itself, universal and external; our existence is but a fleeting moment, the vibration of an atom in a ray of the sun, and our planet is but an island floating in the celestial archipelago to which no thought will ever place any bounds. Never lose sight of the fact that space is infinite, that there is in the void neither height nor depth, neither right nor left, and in time neither begnning nor end. We must understand that our conceptions are relative to our imperfect and transitory impressions, and that the only reality is the Absolute."

CONCLUSION.

(1) The old geocentric theory of the world had its basis in the ancient astronomy. (2) The revolution in astronomy associated with the name of Copernicus swept away the old conception of a central earth, and exerted a powerful influence on theology and philosophy as well as on science. (3) While all branches of human thought influence one another, it may be safely said that the epoch-making work of Newton exerted the greatest influence on intellectual activity in the seventeenth century. The conception of natural law and causality with which we of today are familiar has its origin in Newton's great law of gravitation, which has remained to this day the foundation of all scientific work. Newton, as we have seen, profoundly influenced the whole course of astronomy. Not only so; the Newtonian concept of the solar system as a great machine had something to do with the rise and popularity of the Deistic movement in theology. (4) The work of Herschel had an influence only second to that of Newton. Herschel enormously extended the universe both in space and time. Not only did his telescopes reveal stars sunk in the very depths of space; by his wonderful intuition he grasped the great truth of evolution as the explanation of celestial phenomena, and so, from the mechanistic conception of the universe, astronomers were gradually led to view the universe as an organism, developing from within. (5) Finally, the work of Herschel and of the nineteenth-century astronomers have shown the universe to be a unity.

To the higher thought the chief contribution of modern astronomy undoubtedly is this sense of infinity of space and eternity of time. And theology, which fought for so long against Copernicus, Newton, and Herschel realizes now that it has reason to revere the memory of the astronomers who first unveiled the great truths of the immutability of natural law, the unity of the universe, and its subjection to one great law of nature, the infinity of space and the eternity of time, for in the contemplation of these great themes, science, philosophy, and theology find their meeting-place.

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